US009371106B2

(12) **United States Patent**
Takano

(10) **Patent No.: US 9,371,106 B2**
(45) **Date of Patent: Jun. 21, 2016**

(54) **VEHICLE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/651,779**

(22) PCT Filed: **Dec. 19, 2013**

(86) PCT No.: **PCT/JP2013/084148**

§ 371 (c)(1),
(2) Date: **Jun. 12, 2015**

(87) PCT Pub. No.: **WO2014/098198**

PCT Pub. Date: **Jun. 26, 2014**

(65) **Prior Publication Data**

US 2015/0344091 A1 Dec. 3, 2015

(30) **Foreign Application Priority Data**

Dec. 19, 2012 (JP) 2012-277219
Dec. 19, 2012 (JP) 2012-277220

(51) **Int. Cl.**
B62K 5/08 (2006.01)
B62K 5/10 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC . ***B62K 5/08*** (2013.01); ***B62K 5/027*** (2013.01); ***B62K 5/05*** (2013.01); ***B62K 5/10*** (2013.01); ***B62K 21/00*** (2013.01); ***B62K 25/08*** (2013.01); *B62K 2202/00* (2013.01)

(58) **Field of Classification Search**
CPC B62K 5/027; B62K 5/05
USPC 180/210, 216, 217
See application file for complete search history.

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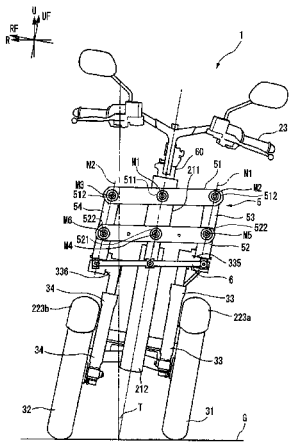
(57) **ABSTRACT**

A vehicle includes a body frame that leans and two front wheels that prevent enlargement of a peripheral construction around a steering shaft above the two front wheels while maintaining a function of a link mechanism. An upper cross portion and a lower cross portion of the link mechanism each include a portion supported at a right end portion and a left end portion thereof and supported on a body frame at a middle portion thereof. The upper cross portion and the lower cross portion preferably have different volumes. Upper displacements that result when a rearward test force is exerted on an upper right bearing and an upper left bearing that support the upper cross portion with the lower cross portion removed, and lower displacements that result when a rearward test force is exerted on a lower right bearing and a lower left bearing that support the lower cross portion with the upper cross portion removed are equal or substantially equal.

13 Claims, 8 Drawing Sheets



(51) **Int. Cl.**

B62K 25/08	(2006.01)
B62K 5/05	(2013.01)
B62K 21/00	(2006.01)
B62K 5/027	(2013.01)

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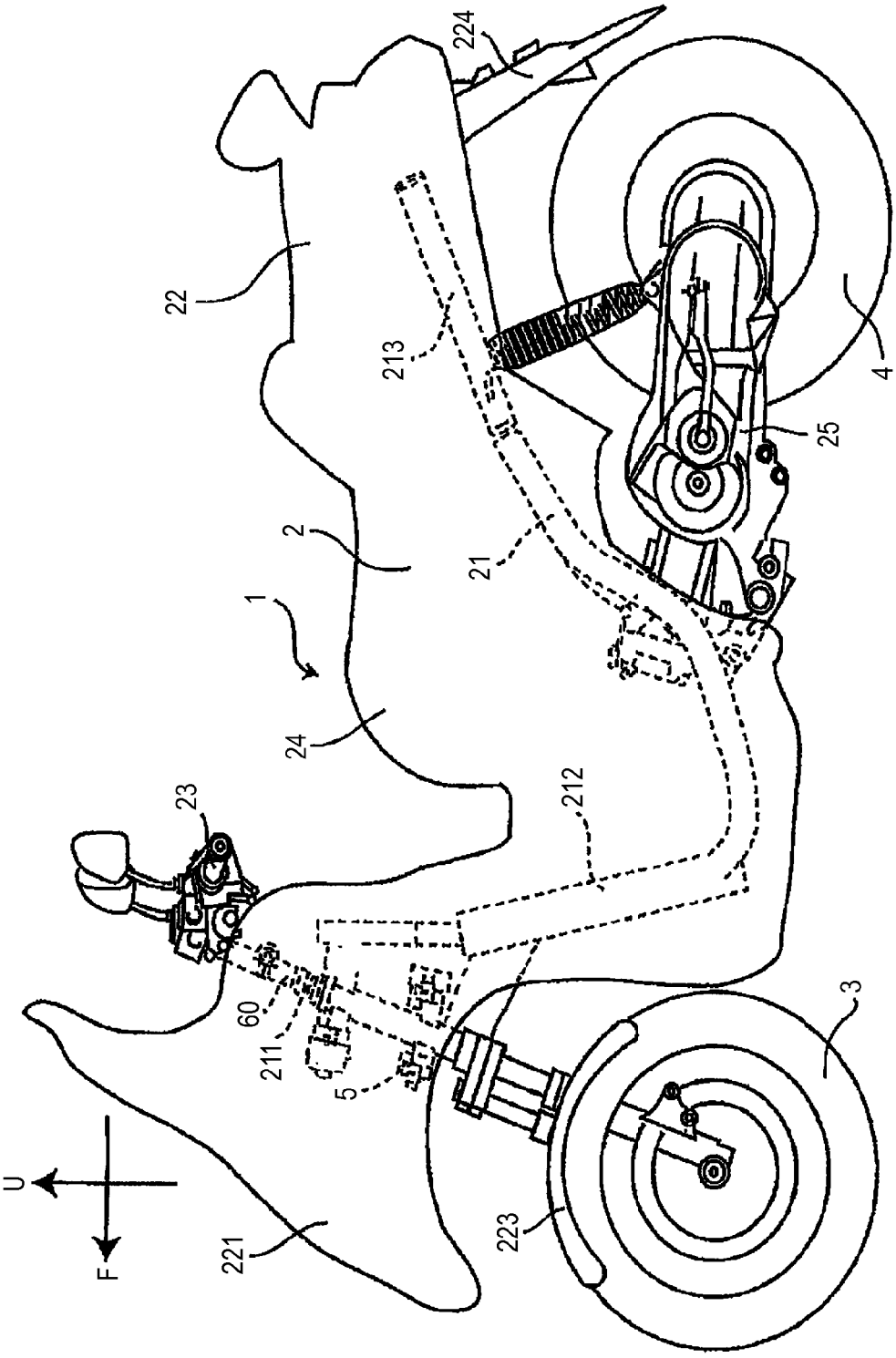

FIG. 1

FIG. 2

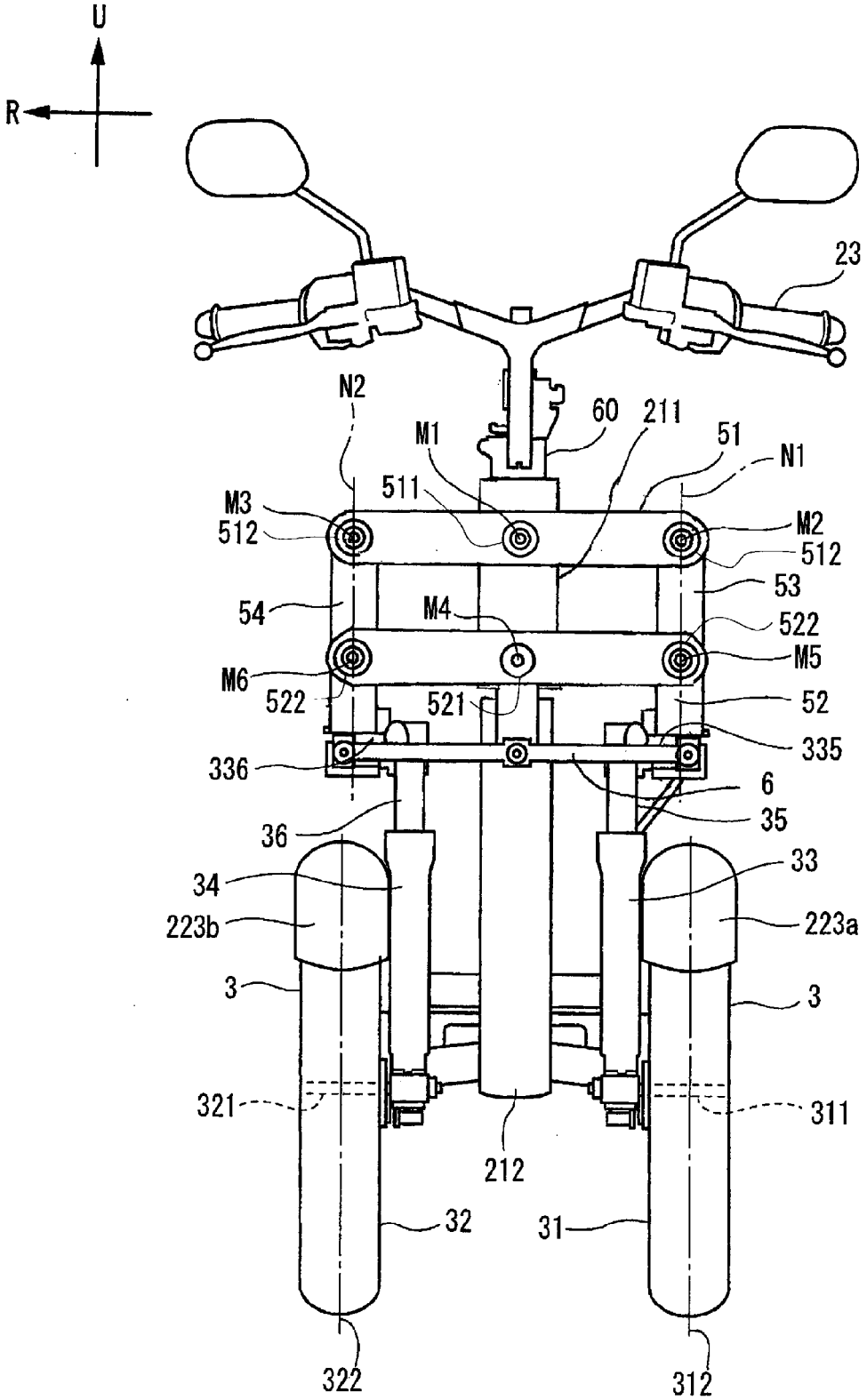
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FIG. 3

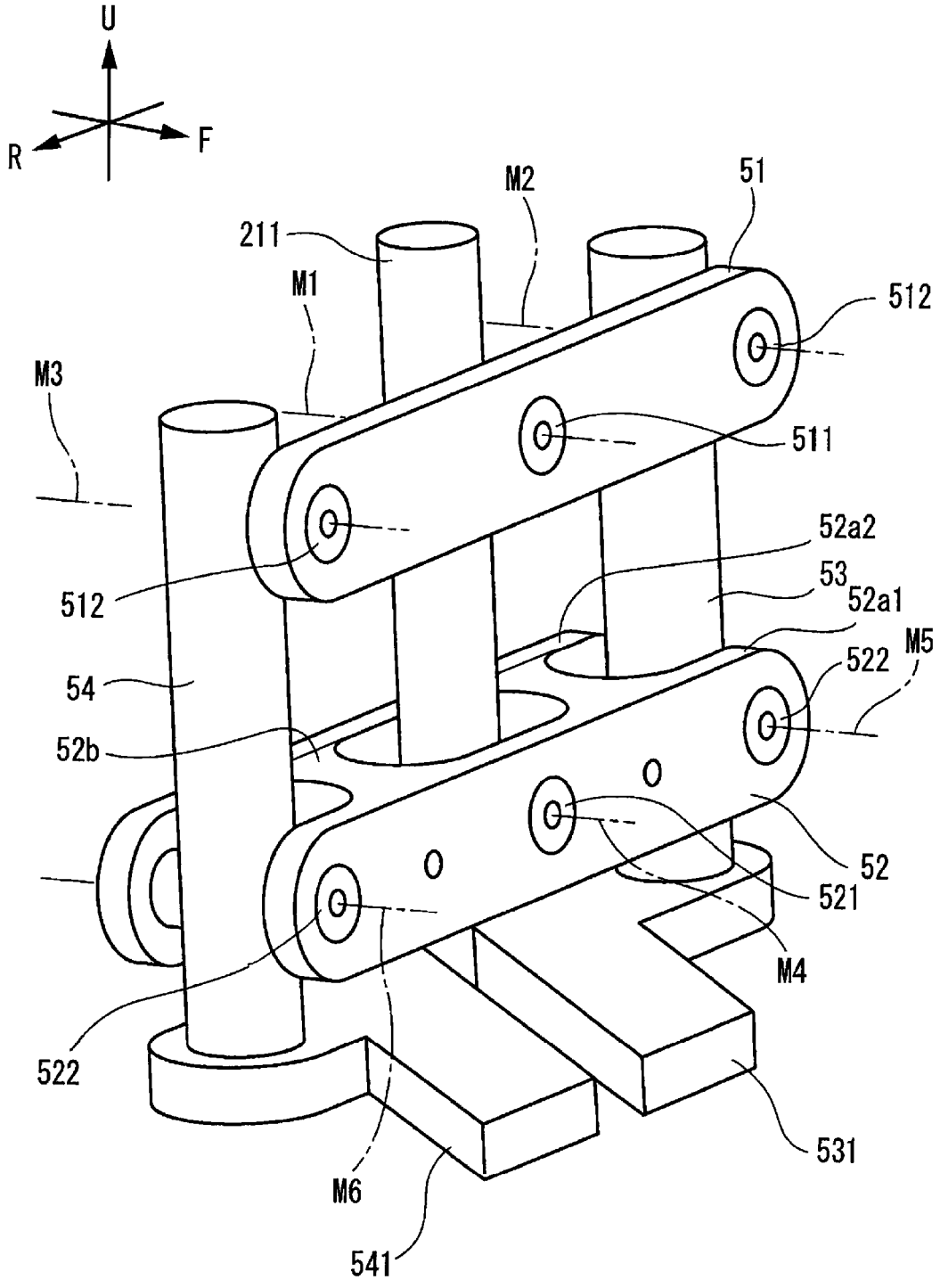
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FIG. 4

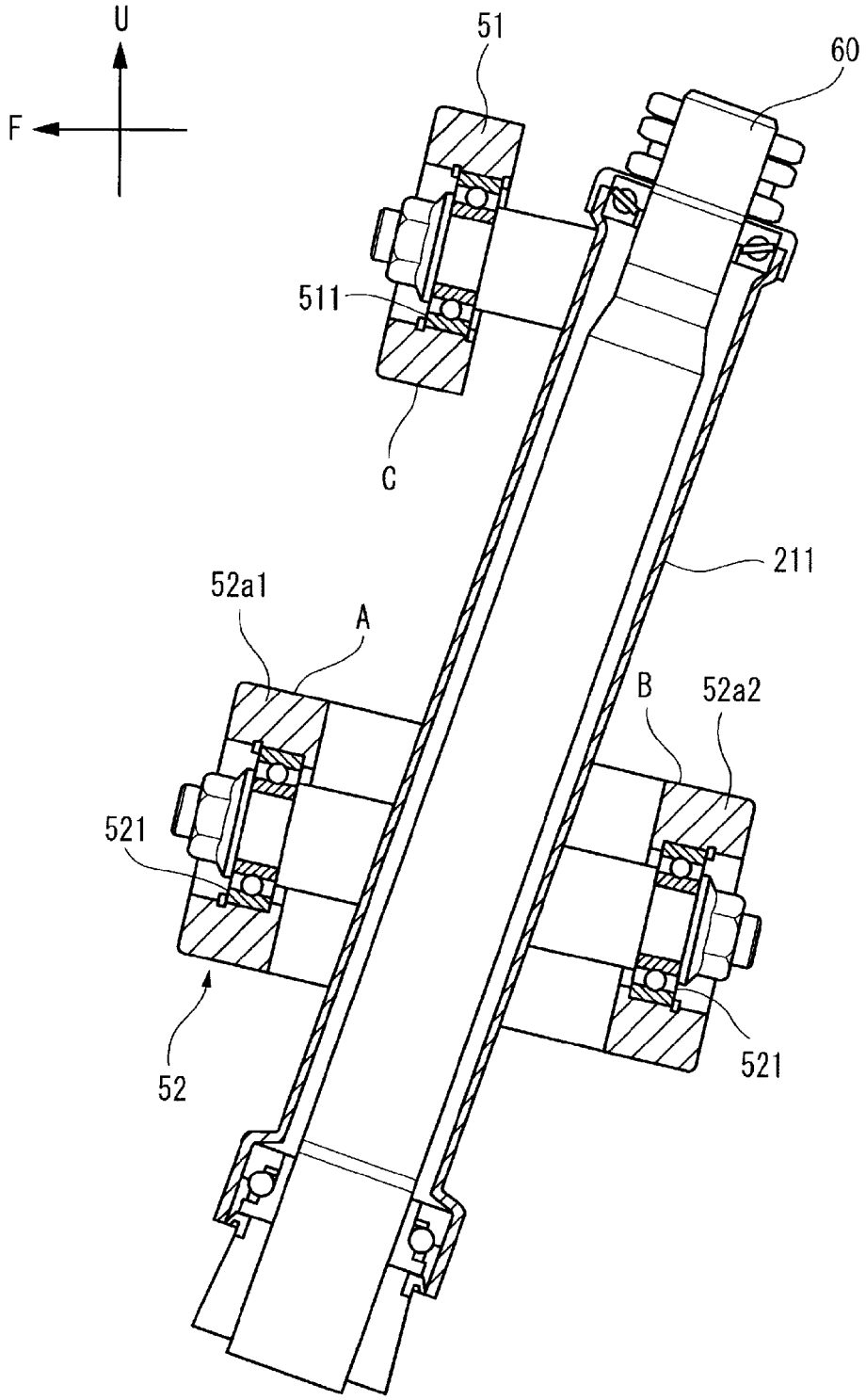

FIG. 5

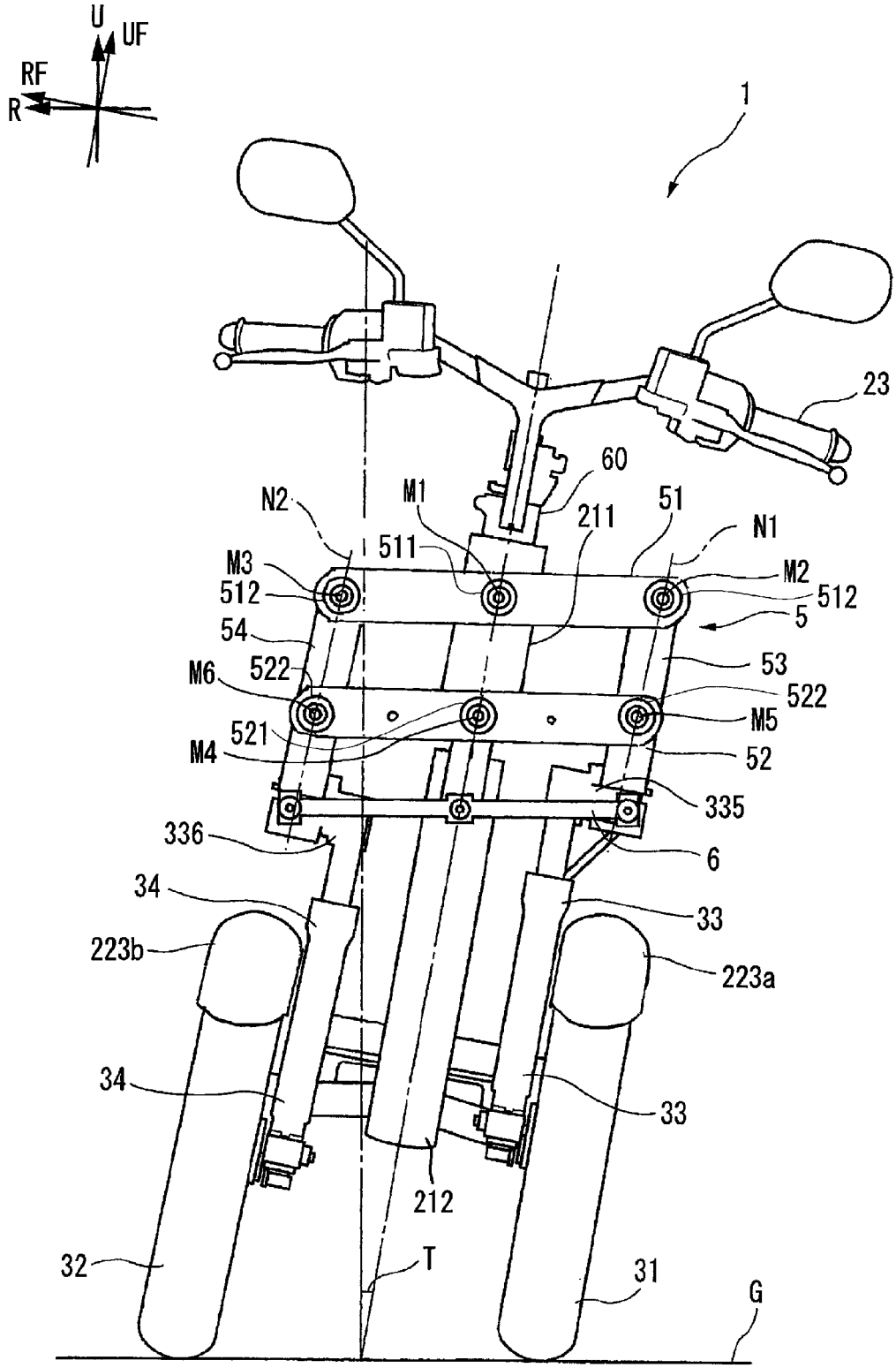
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FIG. 6A

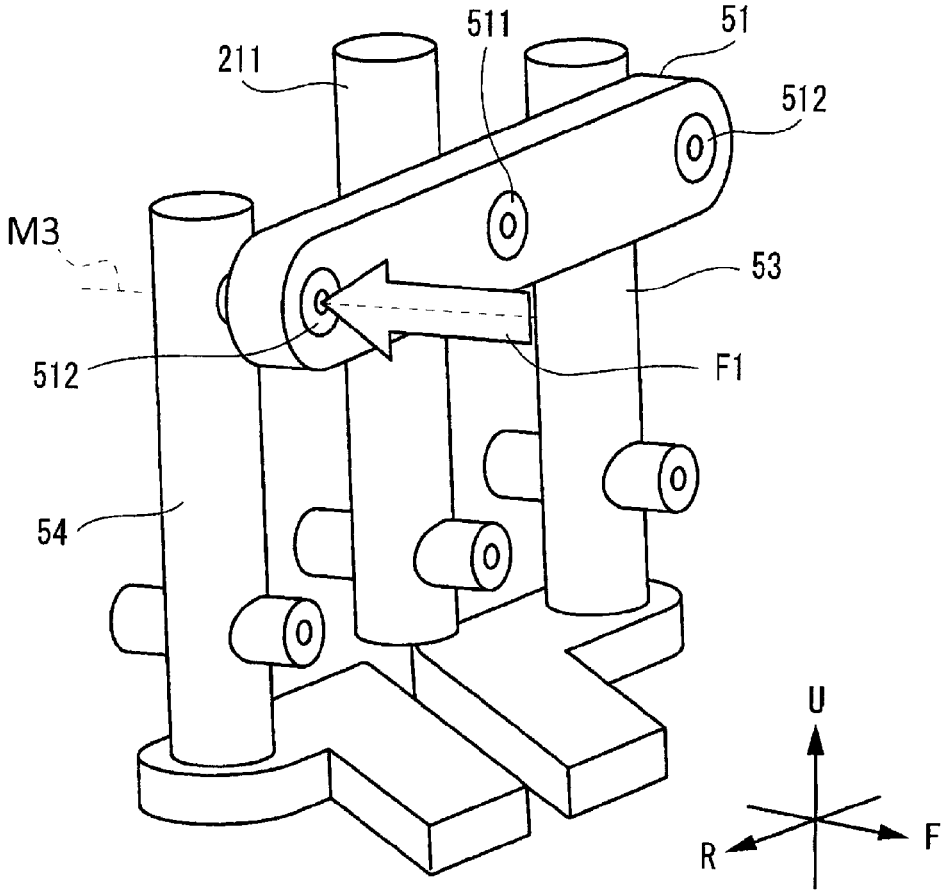
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FIG. 6B

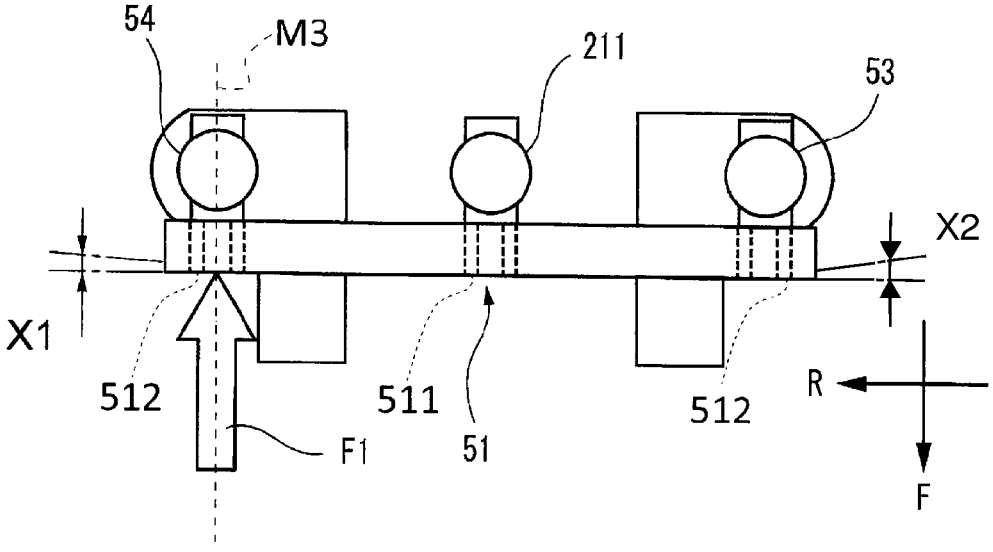
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FIG. 7A

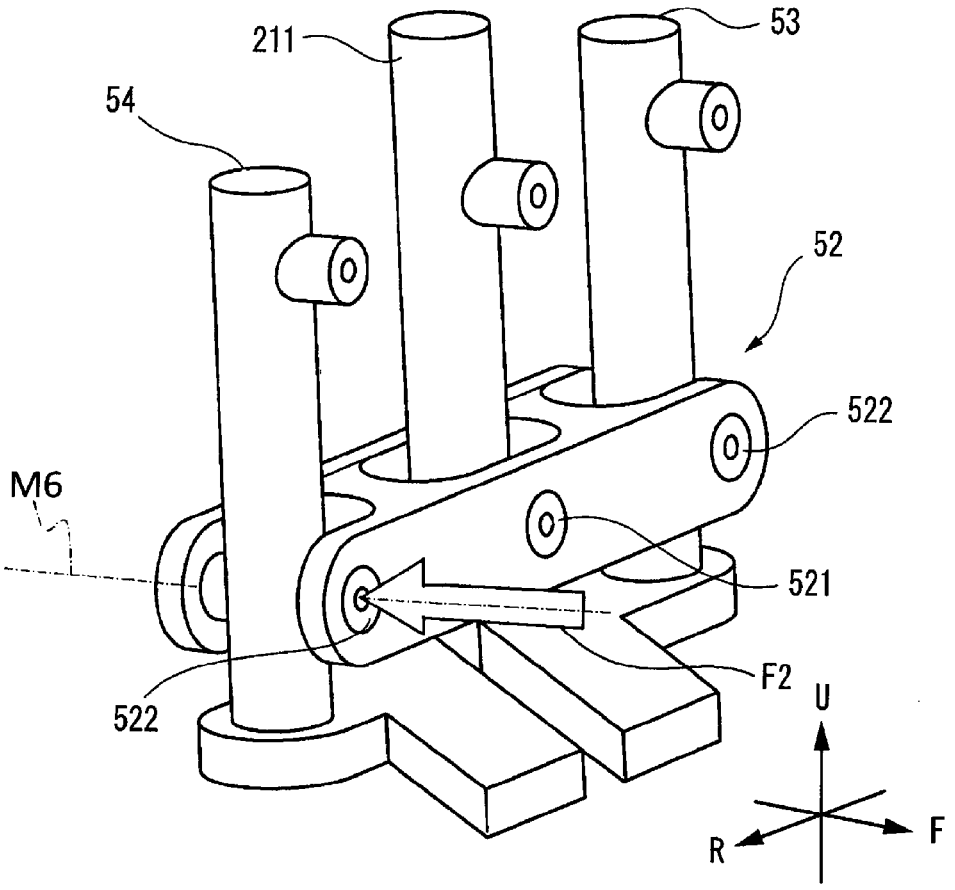
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FIG. 7B

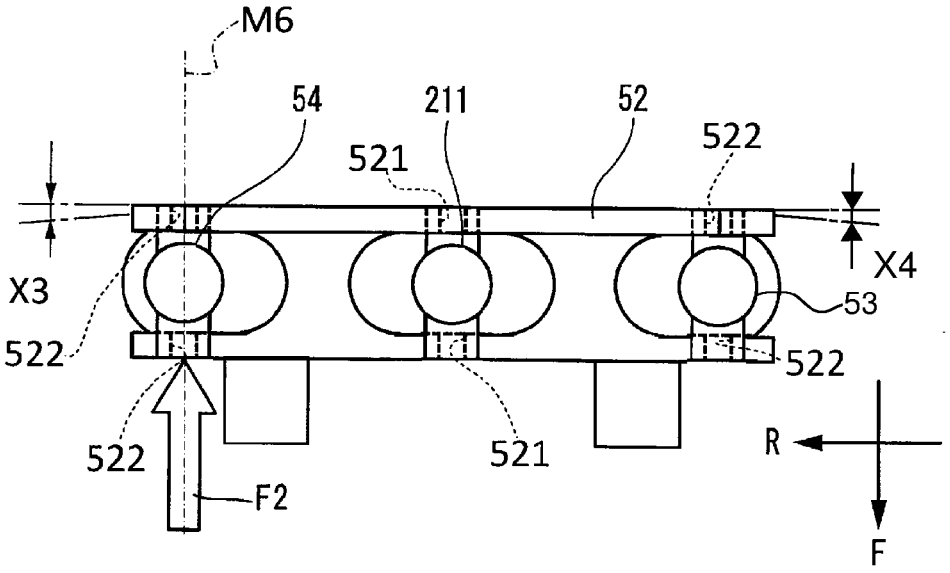
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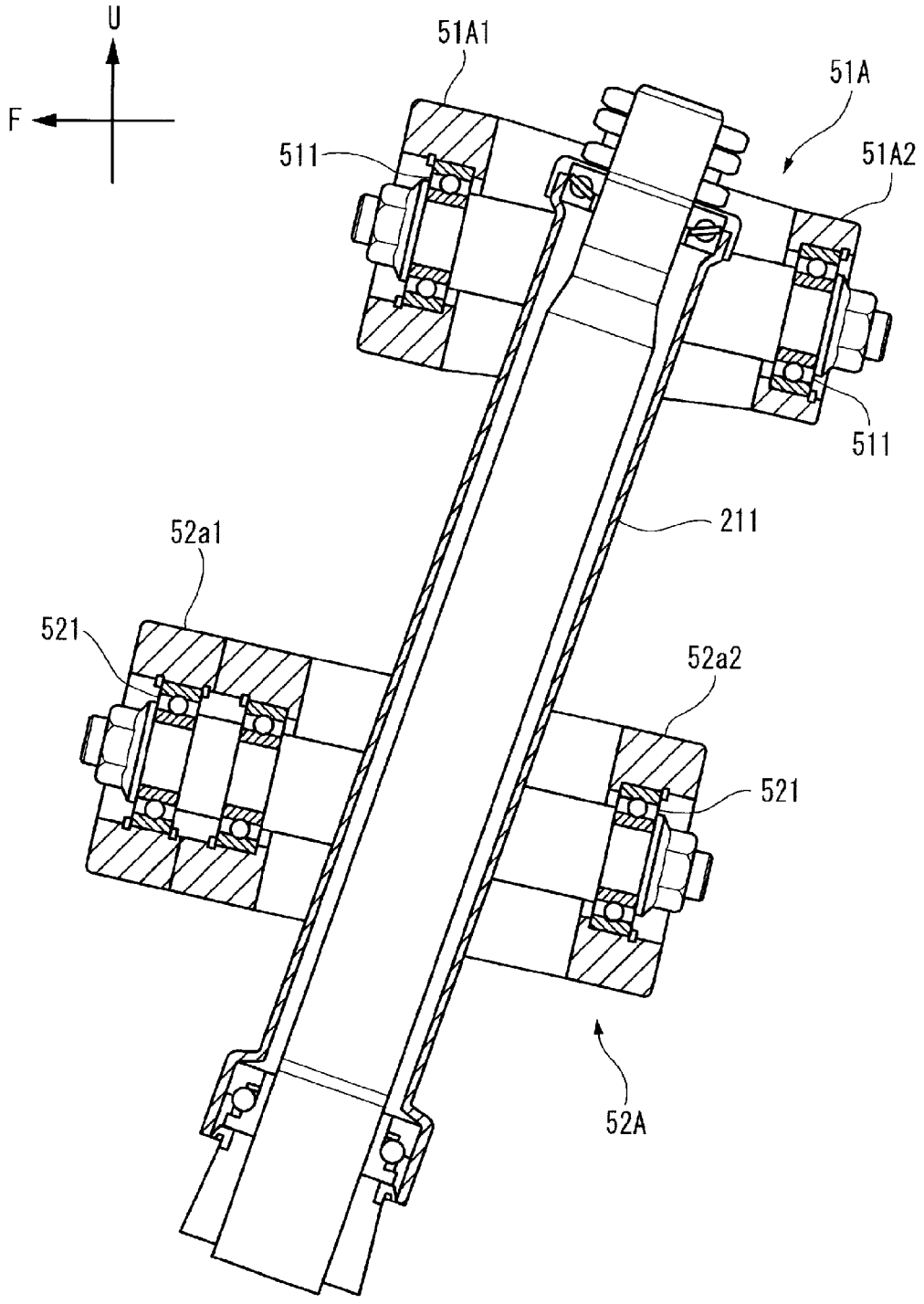
FIG. 8



VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a vehicle that includes a body frame that can lean, and two front wheels.

2. Description of the Related Art

A known vehicle includes a body frame that leans to the left or right when the vehicle is cornering and two front wheels that are aligned in a left-and-right direction of the body frame (for example, refer to Japanese Patent Unexamined publication JP-A-2005-313876; U.S. Design Pat. D547,242S; and Catalogo partidi ricambio, MP3 300 64102 ie LT Mod. ZAPM64102, Piaggio).

The vehicle including the body frame that can lean and the two front wheels includes a link mechanism. The link mechanism includes an upper cross portion and a lower cross portion. In addition, the link mechanism also includes a right side portion which supports right end portions of the upper cross portion and the lower cross, and a left side portion which supports left end portions of the upper cross portion and the lower cross portion. Middle portions of the upper cross portion and the lower cross portion are supported on the body frame forward of a steering shaft. The upper cross portion and the lower cross portion are supported on the body frame so as to turn about axes that extend substantially in a front-and-rear direction of the body frame. The upper cross portion and the lower cross portion turn relative to the body frame as the body frame leans. In response, a relative position of the two front wheels in an up-and-down direction of the body frame changes. The upper cross portion and the lower cross portion are arranged above the two front wheels in the up-and-down direction of the body frame such that the body frame rests in an upright state.

The vehicle including the body frame that can lean and the two front wheels includes a right shock absorbing device which supports the right front wheel so as to move in the up-and-down direction of the body frame and a left shock absorbing device which supports the left front wheel so as to move in the up-and-down direction of the body frame. The right shock absorbing device is supported on the right side portion so as to turn about an axis of the right side portion. The left shock absorbing device is supported on the left side portion so as to turn about an axis of the left side portion. The vehicles described in Japanese Patent Unexamined publication JPA-2005-313876 and U.S. Design Pat. D547,242S further include a handlebar, a steering shaft, and a turn transfer mechanism. The handlebar is fixed to the steering shaft. The steering shaft is supported on the body frame so as to turn relative thereto. When the handlebar is turned, the steering shaft is also turned. The turn transfer mechanism transfers the turning motion of the steering shaft to the right shock absorbing device and to the left shock absorbing device.

The vehicle including the body frame that can lean and the two front wheels includes many on-board components which are provided around the periphery of the steering shaft. The on-board components include lamps such as a headlamp, a radiator, a reservoir tank, electric components such as a horn, and a main switch of the vehicle, a stowage box, a stowage pocket and the like.

In the vehicles described in Japanese Patent Unexamined publication JP-A-2005-313876 and U.S. Design Pat. D547,242S, loads received by the right front wheel and the left front wheel are transferred to the link mechanism by way of the right shock absorbing device or the left shock absorbing device. The loads are transferred to the right side portion or the left side portion from the right shock absorbing device or the left shock absorbing device. The loads are transferred to the upper cross portion and the lower cross portion from the right side portion or the left side portion. The loads are transferred further to the body frame which is positioned around the periphery of the steering shaft from the upper cross portion and the lower cross portion.

The link mechanism includes bearings provided between the right side portion or the left side portion and the upper cross portion and the lower cross portion and bearings provided between the upper cross portion and the lower cross portion and the body frame. These bearings function not only to enable the right side portion or the left side portion to turn smoothly relative to the upper cross portion and the lower cross portion, but also to transfer the loads received by the link mechanism to the body frame.

In addition, the right side portion, the left side portion, the upper cross portion, and the lower cross portion are highly rigid to enhance the function of turning smoothly and the function of transferring the loads. This enlarges the size of right side portion, the left side portion, the upper cross portion, and the lower cross portion. This results in enlargement of the link mechanism including those portions. Further, the movable range of the link mechanism is also enlarged even more.

The vehicles described in Japanese Patent Unexamined publication JP-A-2005-313876 and U.S. Design Pat. D547,242S include the link mechanism provided around the periphery of the steering shaft, and this link mechanism moves as the body frame leans. Because of this, in the vehicle including the body frame that can lean and the two front wheels, the on-board components need to be arranged so that the on-board components do not interfere with the movable range of the link mechanism. In the vehicle that includes the body frame that can lean and the two front wheels, this tends to increase the construction around the periphery of the steering shaft.

SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a vehicle including a body frame that can lean, and two front wheels, which prevents enlargement of a peripheral construction around a steering shaft that is above the two front wheels.

According to a preferred embodiment of the present invention, a vehicle driven by power from a power source includes a left front wheel and a right front wheel that are steerable and disposed in a left-and-right direction as seen from a front of the vehicle; a right shock absorbing device that supports the right front wheel at a lower portion thereof and configured to absorb an upward displacement of the right front wheel in an up-and-down direction of a body frame; a left shock absorbing device that supports the left front wheel at a lower portion thereof and configured to absorb an upward displacement of the left front wheel in the up-and-down direction of the body frame; a link mechanism including a right side portion that supports an upper portion of the right shock absorbing device so as to turn about a right steering axis that extends in the up-and-down direction of the body frame, a left side portion that supports an upper portion of the left shock absorbing device so as to turn about a left steering axis parallel or substantially parallel to the right steering axis, an upper cross portion that includes a right end portion that supports an upper portion of the right side portion via an upper right bearing so as to turn about an upper right axis that extends in a front-and-rear direction of the body frame, a left side portion that supports an upper portion of the left side portion via an upper left bearing so as to turn about an upper left axis parallel or

substantially parallel to the upper right axis, and a middle portion supported on the body frame via an upper middle bearing so as to turn about an upper middle axis parallel or substantially parallel to the upper right axis and the upper left axis, and a lower cross portion that includes a right end portion that supports a lower portion of the right side portion via a lower right bearing so as to turn about a lower right axis parallel or substantially parallel to the upper right axis, a left end portion that supports a lower portion of the left side portion via a lower left bearing so as to turn about a lower left axis parallel or substantially parallel to the upper left axis, and a middle portion supported on the body frame via a lower middle bearing so as to turn about a lower middle axis parallel or substantially parallel to the upper middle axis; a steering shaft supported on the body frame between the right side portion and the left side portion in a transverse direction of the body frame, and including an upper end portion provided higher in the up-and-down direction of the body frame than the lower middle axis and configured to turn about a middle steering axis that extends in the up-and-down direction of the body frame; a handlebar provided at the upper end portion of the steering shaft; and a turn transfer mechanism configured to transfer a turning motion of the steering shaft corresponding to an operation of the handlebar to the right shock absorbing device and to the left shock absorbing device; wherein, in the link mechanism, the upper cross portion has a different volume from the lower cross portion, and a displacement of the upper cross portion resulting when a forward or rearward test force in a direction of the upper right axis is exerted on the upper right bearing with the lower cross portion removed and the upper cross portion mounted, a displacement of the upper cross portion resulting when a force the same in magnitude and direction as the test force is exerted on the upper left bearing with the lower cross portion removed and the upper cross portion mounted, a displacement of the lower cross portion resulting when a force the same in magnitude and direction as the test force is exerted on the lower right bearing with the upper cross portion removed and the lower cross portion mounted, and a displacement of the lower cross portion resulting when a force the same in magnitude and direction as the test force is exerted on the lower left bearing with the upper cross portion removed and the lower cross portion mounted are equal or substantially equal to one another.

The right side portion, the left side portion, the upper cross portion, and the lower cross portion of the link mechanism are highly rigid to enhance the function of turning smoothly and the function of transferring loads. This enlarges the right side portion, the left side portion, the upper cross portion, and the lower cross portion in size. This results in enlargement of the link mechanism including those portions. Further, the movable range of the link mechanism is also enlarged further. The vehicle that includes the body frame that can lean and the two front wheels includes, around the periphery of the steering shaft, a large link mechanism that moves as the body frame leans. Because of this, in the vehicle including the body frame that can lean and the two front wheels, the on-board components are arranged so that the on-board components do not interfere with the movable range of the link mechanism. In the vehicle that includes the body frame that can lean and the two front wheels, this tends to increase the construction around the periphery of the steering shaft.

The inventor of the preferred embodiments of the present invention has analyzed in detail the function of the link mechanism. The link mechanism includes the function of enabling the right side portion or the left side portion to turn smoothly relative to the upper cross portion and the lower cross portion and the function of enabling the upper cross portion and the lower cross portion to turn smoothly relative to the body frame. Additionally, the link mechanism includes the function of transferring loads received by the right side portion and the left side portion to the body frame. The inventor discovered the fact that the load received by the link mechanism includes loads in the direction of the rotational axes of the upper cross portion, the lower cross portion, the left side portion, and the right side portion and loads in directions that extend in the up-and-down direction of the body frame and that are vertical to the rotational axes. Further, the inventor discovered the fact that the smooth operation of the link mechanism is easily maintained by making the rigidity of the upper cross portion to the loads in the direction of the rotational axes equal or substantially equal to the rigidity of the lower cross portion to the loads in the direction of the rotational axes.

According to a preferred embodiment of the present invention, the movable range of the link mechanism changes from a simple shape like a rectangular parallelepiped to an irregular shape by making the volume of the upper cross portion differ from the volume of the lower cross portion. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof. Moreover, the smooth operation of the link mechanism is easy to be maintained since the rigidity of the upper cross portion to the loads in the direction of the rotational axes is equal or substantially equal to the rigidity of the lower cross portion to the loads in the direction of the rotational axes.

Consequently, in the vehicle that includes the body frame that can lean and the two front wheels, it is possible to prevent the enlargement of the peripheral construction of the steering shaft that is located above the two front wheels while the function of the link mechanism is maintained.

The link mechanism is preferably configured such that the upper cross portion is made of a different material from the lower cross portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, when the upper cross portion is made of a material more rigid than a material of which the lower cross portion is made, the volume of the upper cross portion is smaller than the volume of the lower cross portion while the rigidity of the upper cross portion to the loads in the direction of the rotational axes are kept identical to that of the lower cross portion. When the lower cross portion is made of a material more rigid than a material of which the upper cross portion is made, the lower cross portion preferably has a smaller shape than that of the upper cross portion while the rigidity of the upper cross portion to the loads in the direction of the rotational axes is kept identical to that of the lower cross portion. This enables the movable range of the link mechanism to be changed from the simple shape like a rectangular parallelepiped to the irregular shape. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The link mechanism is preferably configured such that the upper cross portion is made of a material identical to the material of the lower cross portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the movable range of the link mechanism

changes from the simple shape like a rectangular parallelepiped to the irregular shape by making the volume of the upper cross portion differ from the volume of the lower cross portion although the upper cross portion and the lower cross portion are made of the same material. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner, and the link mechanism is preferably configured such that a volume of a front portion of the upper cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis differs from a volume of a rear portion of the upper cross portion that is located farther rearward than the link supporting portion.

According to a preferred embodiment of the present invention that includes the body that can lean and the two front wheels, the volume of the front portion of the upper cross portion that is located farther forward than the link supporting portion is different from the volume of the rear portion of the upper cross portion that is located farther rearward than the link supporting portion, and therefore, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape. This enhances the degree of freedom in designing the space around the periphery of the rear portion of the upper cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner, and the link mechanism is preferably configured such that a volume of a front portion of the lower cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis differs from a volume of a rear portion of the lower cross portion that is located farther rearward than the link supporting portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the volume of the front portion of the lower cross portion that is located farther forward than the link supporting portion is different from the volume of the rear portion of the lower cross portion that is located farther rearward than the link supporting portion, and therefore, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape. This enhances the degree of freedom in designing the space around the periphery of the rear portion of the upper cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The link mechanism is preferably configured such that the upper cross portion has a smaller volume than the lower cross portion.

According to a preferred embodiment of the present invention that includes the body frame that can leans and the two front wheels, the upper cross portion has a smaller volume than the lower cross portion, and therefore, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape in which the upper portion is smaller than the lower portion. This enhances the degree of freedom in designing the space at the front portion of the vehicle around the periphery of the upper cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner, and the link mechanism is preferably configured such that a front portion of the upper cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis has a smaller volume than a front portion of the lower cross portion that is located farther forward than the link supporting portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the volume of the front portion of the upper cross portion that is located farther forward than the link supporting portion is smaller than the volume of the front portion of the lower cross portion that is located farther forward than the link supporting portion, and therefore, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape in which the front upper portion is smaller than the front lower portion. This enhances the degree of freedom in designing the front peripheral space of the upper cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner, and the upper cross portion or the lower cross portion is preferably located either forward of or rearward of the link supporting portion, and does not have to be located both forward of and rearward of the link supporting portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the upper cross portion or the lower cross portion is provided only either forward of or rearward of the link supporting portion, and therefore, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape in which the upper portion is smaller than the lower portion. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The link mechanism is preferably configured such that a front end of the upper cross portion is located at a different position from a position where a front end of the lower cross portion is located in the direction of the upper right axis.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape in the front-and-rear direction since the front end of the upper cross portion is located at a different position from the position where the front end of the lower cross portion is located in the direction of the upper

right axis. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The link mechanism is preferably configured such that a rear end of the upper cross portion is located at a different position from a position where a rear end of the lower cross portion is located in the direction of the upper right axis.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the movable range of the link mechanism is able to change from the simple shape like a rectangular parallelepiped to the irregular shape in the front-and-rear direction since the rear end of the upper cross portion is located at a different position from the position where the rear end of the lower cross portion is located in the direction of the upper right axis. This enhances the degree of freedom in designing the periphery of the steering shaft. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner, and the link supporting portion preferably supports the steering shaft in a turnable manner.

According to a preferred embodiment of the present invention that includes the body frame that can leans and the two front wheels, the link supporting portion supports the link mechanism that supports a right front wheel, a left front wheel, a right shock absorbing device, and a left shock absorbing device and is highly rigid. Because of this, the configuration that supports the steering shaft is simplified by making use of the high rigidity. As a result, it is possible to prevent the enlargement of the peripheral construction of the steering shaft.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner. The upper cross portion preferably includes an upper front portion located farther forward than the link supporting portion in the direction of the upper right axis and that is supported at the right end portion, the left end portion, and the middle portion and an upper rear portion positioned farther rearward than the link supporting portion in the direction of the upper right axis and that is supported at the right end portion, the left end portion, and the middle portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the upper cross portion includes the upper front portion positioned farther forward than the link supporting portion and the upper rear portion positioned farther rearward than the link supporting portion, and therefore, the balance between the rigidity and the volume of the upper cross portion is easily controlled. This enhances the degree of freedom in designing the periphery of a lower portion of the steering shaft. This also enhances the degree of freedom in designing the space around the periphery of the lower cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

Compared with a case where only the upper front portion is disposed at the front of the headpipe and no portion is disposed at the rear of the headpipe or a case where only the upper rear portion is disposed at the rear of the headpipe and no portion is disposed at the front of the headpipe, since the upper front portion and the upper rear portion are disposed at the front and rear of the headpipe, respectively, it is easy to enhance the rigidity of the upper cross portion without enlarging the dimension in the front-and-rear direction of the body frame. This prevents the volume of the upper cross portion from being increased while enhancing the rigidity of the upper cross portion. This enhances the degree of freedom in designing the space around the periphery of the upper portion of the link mechanism. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

The body frame preferably includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner. The lower cross portion preferably includes a lower front portion positioned farther forward than the link supporting portion in the direction of the lower right axis and is supported at the right end portion, the left end portion, and the middle portion and a lower rear portion positioned farther rearward than the link supporting portion in the direction of the lower right axis that is supported at the right end portion, the left end portion, and the middle portion.

According to a preferred embodiment of the present invention that includes the body frame that can lean and the two front wheels, the lower cross portion includes the lower front portion positioned farther forward than the link supporting portion and the lower rear portion positioned farther rearward than the link supporting portion, and therefore, the balance between the rigidity and the volume of the lower cross portion is easily controlled. This enhances the degree of freedom in designing the periphery of a lower portion of the steering shaft. This also enhances the degree of freedom in designing the space around the periphery of the rear portion of the lower cross portion. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

Compared with a case where only the lower front portion is disposed at the front of the headpipe and no portion is disposed at the rear of the headpipe or a case where only the lower rear portion is disposed at the rear of the headpipe and no portion is disposed at the front of the headpipe, since the lower front portion and the lower rear portion are disposed at the front and rear of the headpipe, respectively, it is easy to enhance the rigidity of the lower cross portion without enlarging the dimension of the portion in the front-and-rear direction of the body frame. This prevents the volume of the lower cross portion from being increased while enhancing the rigidity of the lower cross portion. This enhances the degree of freedom in designing the space around the periphery of the lower portion of the link mechanism. As a result of this, even though various on-board components that differ in size and the link mechanism are disposed around the periphery of the steering shaft, it is possible to prevent the enlargement of the periphery thereof.

According to the various preferred embodiments of the present invention of a vehicle that includes the body frame that can lean and the two front wheels, it is possible to prevent the enlargement of the peripheral construction of the steering shaft that is located above the two front wheels while the function of the link mechanism is maintained.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more

apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a left side view of a vehicle according to a preferred embodiment of the present invention.

FIG. **2** is an overall front view of the vehicle with a body cover removed.

FIG. **3** is a perspective view of a link mechanism.

FIG. **4** is a side sectional view of the link mechanism.

FIG. **5** is an overall front view showing a state in which the vehicle is caused to lean.

FIGS. **6**A and **6**B schematically show how to measure a rigidity of an upper cross portion.

FIGS. **7**A and **7**B schematically show how to measure a rigidity of a lower cross portion.

FIG. **8** is a drawing similar to FIG. **4** showing a vehicle according to a modified preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a vehicle **1** which is one type of a vehicle according to a preferred embodiment of the present invention will be described with reference to the drawings. In the figures, like reference numerals are given to like or corresponding portions and the description thereof will not be made repeatedly.

In the following description, an arrow F in the drawings denotes a forward direction of the vehicle **1**. An arrow R in the drawings denotes a rightward direction of the vehicle **1**. An arrow U denotes an upward direction. A middle position in a vehicle-width direction indicates a central position in the direction of a width of the vehicle or in a vehicle-width direction of the vehicle as seen from the front. A side of the vehicle in the vehicle-width direction indicates a leftward or rightward direction from the middle position in the vehicle-width direction.

FIG. **1** is an overall side view of the vehicle **1**. In the following description, when front, rear, left, and right are referred to with a view to showing directions, they denote front, rear, left, and right as seen from a rider who rides on the vehicle **1**.

The vehicle **1** includes a vehicle main body **2**, front wheels **3**, and a rear wheel **4**. The vehicle main body **2** includes a body frame **21**, a body cover **22**, a handlebar **23**, a seat **24**, and a power unit **25**.

The body frame **21** supports the power unit **25**, the seat **24** and the like. The power unit **25** includes a power source such as an engine or an electric motor, a transmission and the like. In FIG. **1**, the body frame **21** is shown by broken lines.

The body frame **21** includes a headpipe **211**, a front frame **212**, and a rear frame **213**. The headpipe **211** is disposed at a front portion of the vehicle. A link mechanism **5** is disposed around the periphery of the headpipe **211**.

A steering shaft **60** is inserted into the headpipe **211** so as to turn therein. The steering shaft **60** extends in an up-and-down direction. The handlebar **23** is attached to an upper end of the steering shaft **60**. The front frame **212** is inclined downward from a front end thereof to the rear. The front frame **212** is connected to the headpipe **211** at a position that located farther rearward than an upper cross portion **51**, which will be described below. The rear frame **213** supports the seat **24** and a tail lamp.

The body frame **21** is covered by the body cover **22**. The body cover **22** includes a front cover **221**, front fenders **223**, and a rear fender **224**.

The front cover **221** is positioned forward of the seat **24**. The front cover **221** covers the headpipe **211** and the link mechanism **5**.

The front fenders **223** are provided individually above a pair of left and right front wheels **3**. The front fenders **223** are disposed below the front cover **221**. The rear fender **224** is disposed above the rear wheel **4**.

The front wheels **3** are disposed below the headpipe **211** and the link mechanism **5**. The front wheels **3** are disposed below the front cover **221**.

FIG. **2** is an overall front view of the vehicle **1** with the body cover **22** removed. In FIG. **2**, the front frame **212** and the like are omitted from the illustration.

The vehicle **1** includes the handlebar **23**, the steering shaft **60**, the headpipe **211**, the pair of left and front wheels **3**, and the link mechanism **5**. The link mechanism **5** is disposed around the periphery of the headpipe **211**. The link mechanism **5** is connected to the pair of left and front wheels **3**, that is, a left front wheel **31** and a right front wheel **32**. Additionally, the link mechanism **5** is mounted on the headpipe **211** so as to turn thereon. The link mechanism **5** includes the upper cross portion **51**, a lower cross portion **52**, a left side portion **53**, a right side portion **54**, a first bracket **335**, a second bracket **336**, a left shock absorber **33**, a right shock absorber **34**, and a tie-rod **6**.

The front wheels **3** are aligned side by side in a left-and-right direction of the body frame **21** and include the left front wheel **31** and the right front wheel **32** that are steered. A left front fender **223***a* is disposed above the left front wheel **31**. A right front fender **223***b* is disposed above the right front wheel **32**. The right front wheel **32** is disposed symmetrically with the left front wheel **31** with respect to the headpipe **211** in relation to the left-and-right direction of the body frame **21**.

When referred to in this description, a "rightward direction RF of the body frame **21**" denotes a rightward direction that intersects an axial direction of the headpipe **211** perpendicularly when the vehicle **1** is seen from the front. Additionally, an upward direction UF of the body frame **21** denotes an upward direction of the body frame **21** when the vehicle **1** rests upright. For example, the upward direction of the body frame **21** coincides with the axial direction of the headpipe **211** when the vehicle **1** is seen from the front. As shown in FIG. **2**, with the vehicle **1** is resting in an upright state, the rightward direction RF of the body frame **21** coincides with a rightward direction R in a horizontal direction. Because of this, in FIG. **2**, only the rightward direction R is shown in relation to the horizontal direction. As shown in FIG. **5**, with the vehicle **1** resting to lean in relation to a road surface G, the rightward direction RF of the body frame **21** does not coincide with the rightward direction R in the horizontal direction, and the upward direction UF of the body frame **21** does not coincide with the upward direction in a perpendicular direction.

The left front wheel **31** is connected to the left shock absorber **33**. The left front wheel **31** is connected to a lower portion of the left shock absorber **33**. The left front wheel **31** rotates about a rotational shaft **311**. The rotational shaft **311** extends in the left-and-right direction of the body frame **21**. The left front wheel **31** turns about a turning axis **312**. The vehicle **1** changes its traveling direction as a result of the left front wheel **31** turning about the turning axis **312**.

The right front wheel **32** is connected to the right shock absorber **34**. The right front wheel **32** is connected to a lower portion of the right shock absorber **34**. The right front wheel

32 rotates about a rotational shaft 321. The rotational shaft 321 extends in the left-and-right direction of the body frame 21. The right front wheel 32 turns about a turning axis 322. The vehicle 1 changes its traveling direction as a result of the right front wheel 32 turning about the turning axis 322.

The left shock absorber 33 absorbs impacts exerted on the left front wheel 31. The left shock absorber 33 is disposed below the link mechanism 5 in relation to the up-and-down direction of the body frame 21. The left shock absorber 33 is provided between the left side portion 53 (refer to FIG. 3), which will be described below, and the left front wheel 31. The left shock absorber 33 extends along a left steering axis N1 that extends in a direction in which the steering shaft 60 and the headpipe 211 extend. The left shock absorber 33 is disposed to the left of the headpipe 211 in relation to the left-and-right direction of the body frame 21. The left shock absorber 33 is disposed to the right of the left front wheel 31 in relation to the left-and-right direction of the body frame 21.

The right shock absorber 34 absorbs impacts exerted on the right front wheel 32. The right shock absorber 34 is disposed below the link mechanism 5 in relation to the up-and-down direction of the body frame 21. The right shock absorber 34 is provided between the right side portion 54 (refer to FIG. 3), which will be described below, and the right front wheel 32. The right shock absorber 34 extends along a right steering axis N2 that extends in a direction in which the steering shaft 60 and the headpipe 211 extend. The right shock absorber 34 is disposed to the right of the body frame 21. The right shock absorber 34 is disposed to the left of the right front wheel 32 in relation to the left-and-right direction of the body frame 21.

The tie-rod 6 transfers the steering motion of the handlebar 23 to the left front wheel 31 and the right front wheel 32. By doing so, the left front wheel 31 and the right front wheel 32 are steered by the handlebar 23. The tie-rod 6 is located forward of the headpipe 211. The tie-rod 6 extends in the left-and-right direction of the body frame 21. The tie-rod 6 is disposed below the lower cross portion 52, which will be described below, and above the left front wheel 31 and the right front wheel 32 in relation to the up-and-down direction of the body frame 21. The tie-rod 6 is coupled to a lower end portion of the steering shaft 60. When the steering shaft 60 is turned, the tie-rod 6 moves in the left-and-right direction of the body frame 21.

FIG. 3 is a perspective view of the link mechanism 5 with the left shock absorber 33 and the right shock absorber 34 omitted from the illustration.

The left side portion 53 is disposed to the left of the headpipe 211 in relation to the left-and-right direction of the body frame 21. The right side portion 54 is disposed to the right of the headpipe 211 in relation to the left-and-right direction of the body frame 21. The left side portion 53 and the right side portion 54 are preferably cylindrical or substantially cylindrical members.

The left side portion 53 and the right side portion 54 extend in the up-and-down direction of the body frame 21 with the vehicle resting in the upright state. A mounting piece 531 where the left shock absorber 33 is mounted is provided at a lower end of the left side portion 53. A lower portion of the left side portion 53 supports the left shock absorber 33 so as to turn about the left steering axis N1.

A mounting piece 541 where the right shock absorber 34 is mounted is provided at a lower end of the right side portion 54. A lower portion of the right side portion 54 supports the right shock absorber 34 to turn about the right steering axis N2.

In the present preferred embodiment, the upper cross portion 51 is a single plate-shaped portion that extends in the left-and-right direction when seen from the front of the vehicle. The upper cross portion 51 is provided farther forward to the front of the vehicle than the headpipe 211. The upper cross portion 51 includes an upper middle bearing 511 located at a middle portion of the upper cross portion 51 in relation to the left-and-right direction of the body frame 21 and an upper right bearing 512 and an upper left bearing 512 provided at rightward and leftward portions of the upper cross portion 51 in the left-and-right direction of the body frame 21. An upper middle axis M1 that defines a rotational center of the upper middle bearing 511, an upper left axis M2 that defines a rotational center of the upper left bearing 512, and an upper right axis M3 that defines a rotational center of the upper right bearing 512 are provided so that corresponding rotational shafts are parallel or substantially parallel to one another.

The upper cross portion 51 is mounted on the headpipe 211 via the upper middle bearing 511. This allows the upper cross portion 51 to be supported on the headpipe 211 so as to turn about the upper middle axis M1 relative to the headpipe 211.

The upper cross portion 51 is connected to an upper portion of the left side portion 53 and an upper portion of the right side portion 54 via the upper left bearing 512 and the upper right bearing 512, respectively. This allows the upper cross portion 51 to turn about the upper left axis M2 and the upper right axis M3 relative to the left side portion 53 and the right side portion 54, respectively.

In the present preferred embodiment, the upper cross portion 51 is a single portion that supports the upper portion of the right side portion 54 at a right end portion thereof so as to turn about the upper right axis M3 that extends in a front-and-rear direction of the body frame 21 via the upper right bearing 512, supports the upper portion of the left side portion 53 at a left end portion thereof so as to turn about the upper left axis M2 parallel or substantially parallel to the upper right axis M3 via the upper left bearing 512, and is supported on the body frame 21 at the middle portion thereof so as to turn about the upper middle axis M1 parallel or substantially parallel to the upper right axis M3 and the upper left axis M2 via the upper middle bearing 511.

The lower cross portion 52 has a volume that differs from that of the upper cross portion 51. The lower cross portion 52 extends in the left-and-right direction of the body frame 21 when seen from the front of the vehicle. A length in the left-and-right direction of the lower cross portion 52 is equal or substantially equal to a length in the left-and-right direction of the upper cross portion 51. The lower cross portion 52 is located below the upper cross portion 51 in relation to the up-and-down direction of the body frame 21. The lower cross portion 52 preferably has a rigidity equal or substantially equal to that of the upper cross portion 51. The rigidities of the cross portions will be described in detail below.

The lower cross portion 52 includes a front lower cross portion 52*a*1 and a rear lower cross portion 52*a*2 that hold the headpipe 211 therebetween in the front-and-rear direction of the body frame 21 and a connecting portion 52*b* where the front lower cross portion 52*a*1 and the rear lower cross portion 52*a*2 are connected together with bolts, for example. The connecting portion 52*b* is preferably integral and unitary with the front lower cross portion 52*a*1. The connecting portion 52*b* is located at a position where the connecting portion 52*b* does not interfere with the headpipe 211, the left side portion 53, and the right side portion 54 even when the link mechanism 5 is actuated to operate as will be described below. In the present preferred embodiment, the front lower cross portion 52*a*1 and the rear lower cross portion 52*a*2 preferably have a thickness in the front-and-rear direction of the body frame 21

that is less than half a thickness of the upper cross portion **51** in the front-and-rear direction of the body frame **21**. Additionally, the upper cross portion **51**, the front lower cross portion **52***a***1**, and the rear lower cross portion **52***a***2** are preferably made of the same material, for example, steel having the same modulus of elasticity.

In the front lower cross portion **52***a***1** and the rear lower cross portion **52***a***2** of the lower cross portion **52**, a lower middle bearing **521** is provided at a middle portion in the left-and-right direction of the body frame **21** and a lower left bearing **522** and a lower right bearing **522** are provided at leftward and rightward portions in the left-and-right direction of the body frame **21**. A lower middle axis M**4** that defines a rotational center of the lower middle bearing **521** and a lower left axis M**5** and a lower right axis M**6** that define rotational centers of the lower left bearing **522** and the lower right bearing **522**, respectively, are provided so that corresponding rotational shafts are parallel or substantially parallel to one another. Additionally, the lower middle axis M**4**, the lower left axis M**5**, and the lower right axis M**6** are also provided so as to be parallel or substantially parallel to the upper middle axis M**1**, the upper left axis M**2**, and the upper right axis M**3**. In addition, the positions of the lower left bearing **522** and the lower right bearing **522** in the left-and-right direction of the body frame **21** are preferably the same as the positions of the upper left bearing **512** and the upper right bearing **512** in the left-and-right direction of the body frame **21** when the vehicle **1** is resting in the upright state.

The lower cross portion **52** is mounted on the headpipe **211** via the lower middle bearing **521** in a position located below the upper cross portion **51** in relation to the up-and-down direction of the body frame **21**. This allows the lower cross portion **52** to be supported on the headpipe **211** so as to turn about the lower middle axis M**4** that defines the rotational center of the lower middle bearing **521** relative to the headpipe **211**.

The lower cross portion **52** is connected to a lower portion of the left side portion **53** and a lower portion of the right side portion **54** via the lower left bearing **522** and the lower right bearing **522**, respectively. This allows the lower cross portion **52** to turn about the lower left axis M**5** and the lower right axis M**6** relative to the left side portion **53** and the right side portion **54**, respectively.

In the present preferred embodiment, the lower cross portion **52** preferably includes a combination of two portions. In particular, the lower cross portion **52** includes a right end portion **52***a***2** that supports the lower portion of the right side portion **54** via the lower right bearing **522** so as to turn about the lower light axis M**6** parallel or substantially parallel to the upper right axis M**3**, a left end portion that supports the lower portion of the left side portion **53** via the lower left bearing **522** so as to turn about the lower left axis M**5** parallel or substantially parallel to the upper left axis M**2**, and a middle portion supported on the body frame **21** via the lower middle bearings **521** so as to turn about the lower middle axis parallel or substantially parallel to the upper middle axis and positioned farther rearwards than the headpipe **211**. The portions denoted by reference numeral **52***a***1** and reference numeral **52***b* are positioned forward of the portion described above, and include a right end portion supporting the lower portion of the right side portion **54** via the lower right bearing **522** so as to turn about the lower right axis M**6** parallel or substantially parallel to the upper right axis M**3**, a left end portion supporting the lower portion of the left side portion **53** via the lower left bearing **522** so as to turn about the left side axis M**5** parallel or substantially parallel to the upper left axis M**2**, and a middle portion supported on the body frame **21** via the lower middle bearing **521** so as to turn about the lower middle axis parallel or substantially parallel to the upper middle axis.

In this manner, the upper cross portion **51** is supported on the headpipe **211** so as to turn about the upper middle axis M**1** positioned above the left front wheel **31** and the right front wheel **32** in relation to the up-and-down direction of the body frame **21**. The lower cross portion **52** is supported on the headpipe **211** so as to turn about the lower middle axis M**4** positioned above the left front wheel **31** and the right front wheel **32** and positioned below the upper middle axis M**1** in relation to the up-and-down direction of the body frame **21**. The upper cross portion **51** and the lower cross portion **52** are both positioned above the left front wheel **31** and the right front wheel **32** in relation to the up-and-down direction of the body frame **21**.

Thus, by being configured in the manner described above, the link mechanism **5** is operated within a plane that contains the left side portion **53** and the right side portion **54**. It is noted that the link mechanism **5** is mounted on the headpipe **211**. Because of this, even though the steering shaft **60** is turned in association with the steering of the handlebar **23**, the link mechanism **5** is not turned relative to the body frame **21**.

FIG. **4** is a drawing showing an upper portion of the link mechanism **5** as seen from a side of the vehicle with the vehicle resting in the upright state. As shown therein, in the present preferred embodiment, a lower surface C of the upper cross portion **51** is located between an upper surface A of the front lower cross portion **52***a***1** that defines a front portion and an upper surface B of the rear lower cross portion **52***a***2** that defines a rear portion of the lower cross portion **52** in relation to the front-and-rear direction of the body frame **21**.

Although the link mechanism **5** with the vehicle resting in the upright state is shown in FIG. **4**, the positional relationship described above will be maintained even when the link mechanism **5** is actuated as the vehicle body leans, as will be described below. In particular, even when the link mechanism **5** is actuated, the lower surface C of the upper cross portion **51** is located between the upper surface A of the front lower cross portion **52***a***1** that defines the front portion of the lower cross portion **52** and the upper surface B of the rear lower cross portion **52***a***2** that defines the rear portion of the lower cross portion **52** in relation to the front-and-rear direction of the body frame **21**.

In other words, the link mechanism **5** is provided so that a front end of the upper cross portion **51** and a front end of the lower cross portion **52** are located in different positions in the direction of the upper right axis M**3**.

As shown in FIG. **2**, the first bracket **335** is provided at a lower portion of the left side portion **53**. The first bracket **335** is connected to the left shock absorber **33**. The first bracket **335** is mounted so as to turn relative to the left side portion **53**. The tie-rod **6** is mounted on the first bracket **335** so as to turn relative thereto. A turning axis on which the first bracket **335** and the left side portion **53** turn relative to each other and a turning axis on which the first bracket **335** and the tie-rod **6** turn relative to each other are parallel or substantially parallel to a direction in which the left side portion **53** extends (a left steering axis N**1**).

The second bracket **336** is provided at a lower portion of the right side portion **54**. The second bracket **336** is connected to the right shock absorber **34**. The second bracket **336** is mounted so as to turn relative to the right side portion **54**. The tie-rod **6** is mounted on the second bracket **336** so as to turn relative thereto. A turning axis on which the second bracket **336** and the right side portion **54** turn relative to each other and a turning axis on which the second bracket **336** and the tie-rod **6** turn relative to each other are parallel or substan-

tially parallel to a direction in which the right side portion **54** extends (a right steering axis N**2**).

The steering shaft **60** is supported on the body frame **21** between the left member **53** and the right side portion **54** in the left-and-right direction of the body frame **21**. An upper end portion of the steering shaft **60** is higher in the up-and-down direction of the body frame **21** than the lower middle axis M**4**. The steering shaft **60** turns about a middle steering axis Z that extends in the up-and-down direction of the body frame **21**. The handlebar **23** is provided at the upper end portion of the steering shaft **60**. The tie-rod **6** (an example of a turn transfer mechanism) transfers a turning motion of the steering shaft **60** corresponding to an operation of the handlebar **23** to the right shock absorber **34** and the left shock absorber **33**.

When the steering shaft **60** turns as a result of the handlebar **23** being steered, the tie-rod **6** moves in the left-and-right direction of the body frame **21**. Then, the first bracket **335** turns about the turning axis that connects the first bracket **335** to the left side portion **53** as the tie-rod **6** moves. This moves a connecting portion **52***b* where the first bracket **335** connects to the left shock absorber **33** in the left-and-right direction of the body frame **21**, and the left front wheel **31** turns about a second turning axis **312**.

In this manner, the first bracket **335** transfers the steering of the handlebar **23** to the left front wheel **31**. Similarly, the second bracket **336** transfers the steering of the handlebar **23** to the right front wheel **32**.

FIG. **5** is an overall front view of the vehicle **1** that leans the vehicle body at an angle T in the left-and-right direction relative to a perpendicular direction from the state shown in FIG. **2**. When the vehicle **1** is caused to lean relative to the perpendicular direction, the link mechanism **5** is actuated.

As this occurs, the upper cross portion **51** and the lower cross portion **52** are translated horizontally in the left-and-right direction while the directions in which they extend are kept parallel or substantially parallel to the road surface G. The upper cross portion **51** and the lower cross portion **52** turn about the upper left axis M**2** and the lower left axis M**5**, respectively, relative to the left side portion **53**. Additionally, the upper cross portion **51** and the lower cross portion **52** turn about the upper right axis M**3** and the lower right axis M**6**, respectively, relative to the right side portion **54**.

In this manner, when the vehicle is seen from the front, with the vehicle resting in the upright state, the upper cross portion **51**, the lower cross portion **52**, the left side portion **53**, and the right side portion **54** define a rectangle, and when the vehicle is caused to lean, the link mechanism **5** operates so that the rectangle changes to a parallelogram as the vehicle is caused to lean further.

In the following description, an area where the upper cross portion **51**, the lower cross portion **52**, the left side portion **53**, and the right side portion **54** move is referred to as a movable range of the link mechanism **5**.

In the present preferred embodiment, the link mechanism **5** operates so that a left end of the upper cross portion **51** moves farther horizontally leftwards than a left end of the lower cross portion **52**. When the link mechanism **5** operates in this manner, the left shock absorber **33** and the right shock absorber **34** lean in relation to the vertical direction. When the vehicle **1** leans to the left in relation to the vertical direction in the manner described above, the state of the vehicle **1** changes from the state shown in FIG. **2** to the state shown in FIG. **5**.

The vehicle **1** according to the preferred embodiment is turned by causing the vehicle body to lean while the vehicle **1** is running. Additionally, the directions of the left front wheel **31** and the right front wheel **32** are also changed by operating the handlebar **23**.

Next, rigidities of the upper cross portion **51** and the lower cross portion **52** will be described. In the following description, the rigidities of the upper cross portion **51** and the lower cross portion **52** (hereinafter, when both the cross portions are not discriminated from each other, the upper cross section **51** and the lower cross section **52** are referred to simply as a cross portion) refers to the difficulty that the cross portion has in deflecting when a force acting in the front-and-rear direction of the vehicle body is exerted on the cross portion. In the following description, the upper cross portion **51** and the lower cross section **52** are referred to as a cross portion altogether.

The left front wheel **31** and the right front wheel **32** of the vehicle **1** are each supported independently. Because of this, there are situations in which different forces are exerted on the left front wheel **31** and the right front wheel **32** at different timings. For example, when the brakes are applied or the vehicle **1** rides over irregularities on the road surface, an external force is transferred to the link mechanism **5**. As this occurs, there are situations in which force components in the front-and-rear direction that are different in magnitude or direction are exerted on the left and right sides of the cross portion or in which a force component in the front-and-rear direction is exerted on the left and right of the cross portion at different timings. Even in such a case, the cross portion is required to have a certain difficulty in deflecting when a force in the front-and-rear direction is exerted thereon so as to maintain the smooth operation of the link mechanism **5**. To meet this requirement, the right side portion **54**, the left side portion **53**, the upper cross portion **51**, and the lower cross section **52** of the vehicle **1** of the present preferred embodiment have high rigidities to maintain the smooth operation of the link mechanism **5**.

The right side portion **54**, the left side portion **53**, the upper cross portion **51**, and the lower cross portion **52** that define the link mechanism **5** are highly rigid to enhance the function of turning smoothly and the function of transferring loads. This enlarges the external shapes of the right side portion **54**, the left side portion **53**, the upper cross portion **51**, and the lower cross portion **52**. Additionally, this also enlarges the external shape of the link mechanism **5** made up of those portions. Further, the movable range of the link mechanism **5** is also enlarged further. The vehicle that includes the body frame **21** that can lean and the two front wheels **31**, **32** includes around the periphery of the steering shaft **60** the large link mechanism **5** that moves as the body frame **21** leans. Because of this, in the vehicle including the body frame **21** that can lean and the two front wheels **31**, **32**, on-board components need to be provided so that the on-board components do not interfere with the movable range of the link mechanism **5**. Because of this, in the vehicle that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the construction around the periphery of the steering shaft **60** tends to be increased in size.

The inventor of preferred embodiments of the present invention has analyzed in detail the function of the link mechanism **5**. The link mechanism **5** includes the function of enabling the right side portion **54** or the left side portion **53** to turn smoothly relative to the upper cross portion **51** and the lower cross portion **52** and the function of enabling the upper cross portion **51** and the lower cross portion **52** to turn smoothly relative to the body frame **21**. Additionally, the link mechanism **5** includes the function of transferring loads received by the right side portion **54** or the left side portion **53**

to the body frame **21**. The inventor's analysis has discovered the fact that the load received by the link mechanism **5** includes loads in the direction of the rotational axes (the upper middle axis M**1**, the upper left axis M**2**, the upper right axis M**3**, the lower middle axis M**4**, the lower left axis M**5**, and the lower right axis M**6**) of the upper cross portion **51**, the lower cross portion **52**, the left side portion **53**, and the right side portion **54** and loads in directions that extend in the up-and-down direction of the body frame **21** and that are vertical to the rotational axes. Further, the inventor's analysis has also discovered the fact that the smooth operation of the link mechanism **5** is easily maintained by making the rigidity of the upper cross portion **51** to the load in the direction of the rotational axes equal or substantially equal to the rigidity of the lower cross portion **52**.

The rigidity of the cross portion of the link mechanism **5** includes a rigidity component attributed to the shape, thickness, volume and the like of the cross portion itself and a rigidity component attributed to the type, size and the like of the upper middle bearing **511** or the lower middle bearing **521**. Then, it is possible to know the rigidity of the cross section based on a displacement of the cross portion that will be measured, as described below. It will be shown that the smaller a displacement, the larger the rigidity.

FIGS. **6**A and **6**B are schematic drawings showing how to evaluate the rigidity of the upper cross portion **51**. FIG. **6**A is a perspective view of an upper portion of the link mechanism **5**, and FIG. **6**B is a plan view of the upper portion of the link mechanism **5**. FIGS. **7**A and **7**B are schematic drawings showing how to evaluate the rigidity of the lower cross portion **52**. FIG. **7**A is a perspective view of the upper portion of the link mechanism **5**, and FIG. **7**B is a plan view of the upper portion of the link mechanism **5**.

As shown in FIG. **6**A, the lower cross portion **52** is removed from the headpipe **211**. In this state, the upper middle bearing **511**, the upper left bearing **512**, and the upper right bearing **512** are kept mounted in the upper cross portion **51**. A displacement X**1** of the upper cross portion is measured when a rearward test force F**1** in the direction of the upper right axis M**3** is exerted on the upper right bearing **512** with the lower cross portion **52** removed.

Similarly, a displacement X**2** of the upper cross portion **51** is measured when a force the same in magnitude and direction (a rearward direction in the direction of the upper left axis M**2**) as the test force F**1** is exerted on the upper left bearing **512** with the lower cross portion **52** removed.

Next, as shown in FIGS. **7**A and **7**B, the upper cross portion **51** is removed from the headpipe **211**. In this state, the lower middle bearing **521**, the lower left bearing **522**, and the lower right bearing **522** are kept mounted in the lower cross portion **52**. A displacement X**3** of the lower cross portion **52** is measured when a force the same in magnitude and direction (a rearward direction in the direction of the lower right axis M**6**) as the test force F**1** is exerted on the lower right bearing **522** with the upper cross portion **51** removed.

Similarly, a displacement X**4** of the lower cross portion **52** is measured when a force F**2** the same in magnitude and direction (a rearward direction in the direction of the lower left axis M**5**) as the test force F**1** is exerted on the lower left bearing **522** with the upper cross portion **51** removed.

As in the upper left bearing **512** and the lower left bearing **522** or the upper right bearing **512** and the lower right bearing **522**, the test force is exerted only on one of the left and right bearings of the upper cross portion **51** and the lower cross portion **52**. By doing so, a force exerted on the upper cross portion **51** and the lower cross portion **52** when the brakes are applied or the vehicle rides over irregularities on the road surface is simulated.

When the displacements X**1**, X**2**, X**3**, and X**4** are measured in the manner described above, in the vehicle **1** of the present preferred embodiment, the displacements X**1** to x**4** are preferably equal or substantially equal to one another. Here, it is understood that the displacements X**1** to X**4** are defined to be equal or substantially equal to one another when a difference between a largest displacement and a smallest displacement in terms of absolute value is equal to or smaller than 20% of a mean value of the displacements X**1** to X**4**.

In the vehicle **1** of the present preferred embodiment, the upper cross portion **51** does not include a member that corresponds to the connecting portion **52***b* of the lower cross portion **52**. In particular, the upper cross portion **51** is higher than the headpipe **211**, and no cross portion **51** is provided farther rearward than the headpipe **211**. In contrast with this, the lower cross portion **52** includes the portions that are located at the front and rear of the headpipe **211**.

Further, the upper middle bearing **511** is provided farther forward than the headpipe **211**, and no bearing is provided farther rearward than the headpipe **211**. In contrast with this, the lower middle bearings **521** are provided at the front and rear sides of the headpipe **211**. The same bearings are preferably used for the upper middle bearing **511** and the lower middle bearings **521**.

Because of this, in the vehicle **1** of the present preferred embodiment, the rigidity of the upper cross portion **51** is preferably equal or substantially equal to that of the lower cross portion **52** by using at least one of the following configurations (1) to (4) or a combination thereof. Configuration (1), a thickness in the front-and-rear direction of the upper cross portion **51** is larger than the thickness of each of the front lower cross portion **52***a***1** and the rear lower cross portion **52***a***2** of the lower cross portion **52**. Configuration (2), the upper cross portion **51** is larger than the front lower cross portion **52***a***1** that defines the front portion of the lower cross portion **52**. Configuration (3), the upper middle bearing **511** of the upper cross portion **51** is larger than the lower middle bearings **521** of the lower cross portion **52**. Configuration (4), the upper middle bearing **511** of the upper cross portion **51** includes a plurality of bearings. All the configurations (1) to (4) may be used.

According to the vehicle **1** of the present preferred embodiment, the movable range of the link mechanism **5** is changed from a simple shape like a rectangular parallelepiped to an irregular shape by making the volume of the upper cross portion **51** that includes the portions supporting the right side portion **54** and the left side portion **53** and the portion supported on the body frame **21** differ from the volume of the lower cross portion **52** that includes the portions supporting the right side portion **54** and the left side portion **53** and the portion supported on the body frame **21**.

The inventor discovered that it is preferable from the analysis to make the rigidity of the upper cross portion **51** equal or substantially equal to the rigidity of the lower cross portion **52** to enable the smooth operation of the link mechanism **5**. It is general practice and is reasonable to make the upper cross section and the lower cross section identical to each other in order for them to have the same rigidity.

However, the inventor has discovered that the utilization efficiency of the peripheral space of the steering shaft **60** cannot be enhanced in case the upper cross portion and the lower cross portion are identical. Then, the inventor realized that it is useful to make the volume of the upper cross portion **51** different from the volume of the lower cross portion **52** to

enhance the utilization efficiency of the peripheral space of the steering shaft **60** while making the volume of the upper cross portion **51** different from the volume of the lower cross portion **52**. In the event that the volume of the upper cross portion **51** differs from the volume of the lower cross portion **52**, the upper cross portion **51** and the lower cross portion **52** are able to have different shapes. The link mechanism **5** is allowed to have an irregular movable range by making use of the configuration in which the upper cross portion **51** and the lower cross portion **52** have different shapes, thus making it possible to make effective use of the peripheral space of the steering shaft **60**. Further, the upper cross portion **51** and the lower cross portion **52** preferably have the same rigidity, and therefore, the smooth operation of the link mechanism **5** is easily maintained.

In the present preferred embodiment, the upper cross portion **51** is positioned farther forward than the headpipe **211** and no cross portion is provided farther rearward than the headpipe **211**. Additionally, the lower cross portion **52** includes the portion positioned farther rearward than the headpipe **211** and the portion positioned farther forward than the headpipe **211**. This makes the movable range of the link mechanism **5** into a shape in which, in the front-and-rear direction of the body frame **21**, a dimension increases from top to bottom in relation to the up-and-down direction of the body frame **21**. This makes it easy to dispose on-board components in an area around the periphery of the steering shaft **60** and near the upper portion of the link mechanism **5**.

Specifically, the upper cross portion **51** preferably includes a single plate-shaped member and, as shown in FIG. **4**, no member of the link mechanism **5** is provided at the upper portion of and farther rearward than the link mechanism **5**. This enables an upper portion of the space where the link mechanism **5** operates (the movable range of the link mechanism) smaller than the movable range of the link mechanism of Japanese Patent Unexamined publication JP-A-2005-313876. Then, the body frame or accessories can be disposed in the upper space farther rearward than the link mechanism **5**. Alternatively, the front cover **221** is smaller in size by an area corresponding to the upper rear space. Here, accessories include a hydraulic unit of ABS (Antilock Brake System), headlamp, horn, turn signals, radiator, battery, anti-theft device, brake hose, brake wire, fasteners for brake hose and brake wire, body cover, various meters, and the like.

In the space at the front portion of the vehicle, a member of the body frame is large or an additional member is disposed in the upper space located farther rearward than the link mechanism **5**, such that it is possible to enhance the rigidity of the vehicle.

Alternatively, the space may be used to dispose the accessories or as a storage space. By doing so, positions where to dispose the equipment are freely designed at the front portion of the vehicle. Additionally, it is possible to improve the external design.

In this manner, according to the vehicle of the present preferred embodiment, the degree of freedom in designing the periphery of the steering shaft **60** is enhanced by changing the movable range of the link mechanism **5** from the simple shape like a rectangular parallelepiped to the irregular shape. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery.

Moreover, even though the volume of the upper cross portion **51** is made to differ from the volume of the lower cross portion **52** to change the movable range of the link mechanism **5** from the simple shape like a rectangular parallelepiped to the irregular shape, the rigidity of the upper cross portion **51** to the load in the direction of the rotational axis is kept equal or substantially equal to that of the lower cross portion **52**. This makes it easy to maintain the smooth operation of the link mechanism **5**.

Consequently, it is possible to prevent the enlargement of the peripheral construction of the steering shaft **60** located above the two front wheels **31**, **32** while the function of the link mechanism **5** is maintained in the vehicle **1** that includes the body frame **21** that can lean and the two front wheels **31**, **32**.

In particular, a display portion and the body frame are disposed densely behind the headpipe **211** in many cases. Because of this, it is preferably that no member of the upper cross portion **51** is provided on the headpipe **211** since the space is effectively used for other applications. For example, the front frame **212** can be connected directly to the headpipe **211** without interposing a support member or the like therebetween, thus making it possible to enhance the rigidities of the front frame **212** and the headpipe **211**.

Additionally, the upper cross portion **51**, the lower cross portion **52**, the left side portion **53**, and the right side portion **54** of the link mechanism **5** are turnably supported by the bearings **511**, **512**, **521**, and **522**. This enhances the rigidity of the link mechanism **5**.

In the vehicle **1** according to the present preferred embodiment, the material of the upper cross portion **51** is preferably the same as the material of the lower cross portion **52** in the link mechanism **5**. Even though the material of the upper cross portion **51** is preferably the same as the material of the lower cross portion **52**, as has been described above, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to the irregular shape by making the volume of the upper cross portion **51** different from the volume of the lower cross portion **52**. This enhances the degree of freedom in designing the periphery of the steering shaft **60**. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery thereof.

Alternatively, different from the preferred embodiments described above, different materials may be used for the upper cross portion **51** and the lower cross portion **52** of the link mechanism **5**. In the event that the upper cross portion **51** is made of a material higher in rigidity than a material of which the lower cross portion **52** is made, the volume of the upper cross portion **51** is preferably smaller than that of the lower cross portion **52** while making the rigidity of the upper cross portion **51** to the load in the direction of the rotational axis equal or substantially equal to that of the lower cross portion **52**. This enables the movable range of the link mechanism **5** to be changed from the simple shape like a rectangular parallelepiped to the irregular shape. This enhances the degree of freedom in designing the periphery of the steering shaft **60**. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery.

Contrary to this, in the event that the upper cross portion **51** is made of a material higher in rigidity than a material of which the lower cross portion **52** is made, the volume of the upper cross portion **51** is preferably made smaller than that of the lower cross portion **52** while making the rigidity of the upper cross portion **51** to the load in the direction of the rotational axis equal or substantially equal to that of the lower cross portion **52**.

In the vehicle **1** according to the present preferred embodiment, in the link mechanism **5**, the volume of the upper cross portion **51** is smaller than the volume of the lower cross portion **52**. According to the vehicle of the present preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the volume of the upper cross portion **51** is smaller than that of the lower cross portion **52**, and therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to the irregular shape in which the upper portion is smaller than the lower portion. This enhances the degree of freedom in designing the peripheral space of the upper cross portion **51** that is located at the front of the vehicle. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery.

As shown in FIG. **4**, in the vehicle **1** according to the present preferred embodiment, the body frame **21** includes the headpipe **211** that turnably supports the upper cross portion **51** and the lower cross portion **52**. The upper cross portion **51** is provided forward of the headpipe **211** and no such member is provided behind the headpipe **211**.

According to the vehicle of the present preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the upper cross portion **51** is provided only at the front of the headpipe **211**, and therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to the irregular shape in which the upper portion is smaller than the lower portion. This enhances the degree of freedom in designing the periphery of the steering shaft **60**. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery.

Different from the preferred embodiments described above, a configuration may be used in which the upper cross portion **51** is provided rearward of the headpipe **211**, and no such member is provided forward of the headpipe **211**. Even with this configuration, as with the configuration described above, the movable range of the link mechanism **5** changes into the irregular shape in which the upper portion is smaller than the lower portion.

Alternatively, a configuration may be used in which the lower cross portion **52** is provided either forward of or rearward of the headpipe **211** and does not have to be provided at both locations. This configuration also allows the movable range of the link mechanism **5** to change into an irregular shape in which a lower portion is smaller than an upper portion.

As shown in FIG. **4**, in the vehicle according to the present preferred embodiment, a front end of the upper cross portion **51** and a front end of the lower cross portion **52** are provided in different positions in relation to the direction of the upper right axis M**3**.

According to the vehicle that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the front end of the upper cross portion **51** and the front end of the lower cross portion **52** are provided in the different positions in the direction of the upper right axis M**3**, and therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to a shape irregular in the front-and-rear direction. This enhances the degree of freedom in designing the periphery of the steering shaft **60**. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery thereof.

In the vehicle according to the present preferred embodiment, the link mechanism **5** is configured such that the rear end of the upper cross portion **51** and the rear end of the lower cross portion **52** are provided in different positions in the direction of the upper right axis.

According to the vehicle of the present preferred embodiment, the rear end of the upper cross portion **51** and the rear end of the lower cross portion **52** are provided in different positions in the direction of the upper right axis M**3**, and therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to a shape irregular in the front-and-rear direction. This enhances the degree of freedom in designing the periphery of the steering shaft **60**. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery.

In the vehicle according to the present preferred embodiment, the headpipe **211** turnably supports the upper cross portion **51** and the lower cross portion **52** turnably supports the steering shaft **60**.

According to the vehicle **1** of the present preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the headpipe **211** supports the link mechanism **5** that supports, in turn, the right front wheel **32**, the left front wheel **31**, the right shock absorber **34**, and the left shock absorber **33** and includes a high rigidity. Because of this, the steering shaft **60** is supported by a highly rigid structure, such that the configuration in which the steering shaft **60** is supported is simplified. As a result, it is possible to prevent the enlargement of the peripheral construction of the steering shaft **60**.

In addition, the lower cross portion **52** is configured so as to include the front lower cross portion **52***a***1** and the rear lower cross portion **52***a***2** that hold the headpipe **211** from the front and rear therebetween. In the lower cross portion **52**, it is possible to obtain the high rigidity by using a thin plate material.

In addition, the upper cross portion **51** is mounted on the headpipe **211** only via the single upper middle bearing **511**. In contrast to this, the lower cross portion **52** includes the lower middle bearings **521** that are provided at the front and rear of the headpipe **211**. Namely, the lower cross portion **52** is supported on the headpipe **211** at the two points that are spaced apart from each other in the front-and-rear direction. By using this configuration, is high rigidity of the lower cross portion **52** is easily provided. Additionally, the loads that are exerted on the lower middle bearings **521** that support the lower cross portion **52** are mitigated. This allows the use of a bearing having a relatively small withstand load for the lower middle bearing **521** which is required to have a large withstand load.

In addition, the upper cross portion **51** is provided only at the front of the headpipe **211**, and the front lower cross portion **52***a***1** and the rear lower cross portion **52***a***2** of the lower cross portion **52** are provided at both the front side and the rear side of the headpipe **211**. By using this configuration, the supporting rigidity with which the lower cross portion **52** supports the left side portion **53** and the right side portion **54** becomes larger than the supporting rigidity with which the upper cross portion **51** supports the left side portion **53** and the right side portion **54**. In this manner, the left side portion **53** and the right side portion **54** are supported by the lower cross portion **52** that has a large supporting rigidity in the positions near the front wheels **31**, **32**. This ensures that the link mecha-

nism **5** has the rigidity required to withstand the external forces exerted on the front wheels **31**, **32** with ease.

Additionally, as described in FIG. **4**, in this preferred embodiment, the lower surface C of the upper cross portion **51** is located between the upper surface A of the front lower cross portion **52***a***1** that defines the front portion and the upper surface B of the rear lower cross portion **52***a***2** that defines the rear portion of the lower cross portion **52** in relation to the front-and-rear direction of the body frame **21**. By using this configuration, even though the link mechanism **5** is actuated as a result of the vehicle **1** being caused to lean, there is no such situation that the upper cross portion **51** interferes with the lower cross portion **52**. This allows a distance between the upper cross portion **51** and the lower cross portion **52** to be reduced, thus making it possible to reduce a dimension in the up-and-down direction of the link mechanism **5**. This allows the space at the front portion of the vehicle to be further effectively used.

In addition, in the present preferred embodiment, the displacement of the upper cross portion **51** resulting when the rearward test force F**1** is exerted on the upper cross portion **51** is equal or substantially equal to the displacement of the lower cross portion **52** resulting when the forward test force F**2** is exerted on the lower cross portion **52**, and the displacement of the upper cross portion **51** resulting when the forward test force F**1** is exerted on the upper cross portion **51** is equal or substantially equal to the displacement of the lower cross portion **52** resulting when the rearward test force F**2** is exerted on the lower cross portion **52**.

While the present invention has been described with respect to the preferred embodiments above, the technical scope of the present invention is not limited by the scope described in the preferred embodiments described above. It is obvious to those skilled in the art to which the present invention pertains that various alterations or improvements can be made to the preferred embodiments.

For example, in the preferred embodiments above, the upper cross portion **51** and the lower cross portion **52** are described as being made of the same material and having different volumes so that the displacements X**1** to X**4** are equal or substantially equal by making their volumes different from each other. However, the approach of making the displacements X**1** to X**4** equal or substantially to one another by making the volumes different from each other is not limited to the approach described in the preferred embodiments. For example, different materials may be used, and further, the volumes may also be different.

For example, the upper cross portion **51** may be made of a material having a higher rigidity than that of a material of the lower cross portion **52**. By using this approach, the volume of the upper cross portion **51** is reduced by reducing the thickness of the upper cross portion **51**. Then, the upper portion of the link mechanism **5** is made smaller in size, such that the peripheral space of the upper portion of the link mechanism **5** can be used for other applications. In particular, this enhances the degree of freedom in designing the peripheral space of the upper cross portion **51**.

In addition, in the preferred embodiments described above, plate members having the same shape are used for the upper cross portion **51** and the lower cross portion **52**, and in order for the upper cross portion **51** and the lower cross portion **52** to have different volumes, the upper cross portion **51** includes one plate member, while the lower cross portion **52** includes two plate members. However, the approach of having the different volumes is not limited to the approach described in the preferred embodiments. For example, it is possible to use an approach of using members which are different in cross-sectional area and cross-sectional shape in addition to different thickness for the upper cross portion **51** and the lower cross portion **52**, or an approach of providing or not providing a reinforcement rib to enhance the rigidity of the upper cross portion **51** and the lower cross portion **52**. Further, different bearings may be used for the upper middle bearing **511** and the lower middle bearings **521**. It is noted that when referred to herein, the description that the volumes of the upper cross portion and the lower cross portion differ indicates that a difference in volume that does not largely affect the rigidities of the cross sections is not included in the difference in volume referred to above.

In the preferred embodiments, the upper space located behind the link mechanism **5** is described as being used for other applications including the application in which accessories are disposed in the space, the present invention is not limited thereto. For example, a configuration may be used in which the rigidities of the upper cross portion **51** and the lower cross portion **52** are equal or substantially equal, and the single upper cross portion **51** is provided behind the headpipe **211** so that the front upper space of the link mechanism **5** is used for other applications.

In addition, a configuration may be used in which the link mechanism **5** is constructed upside down compared with the construction described in the preferred embodiments above. Specifically, an upper cross portion **51** includes two cross portions, that is, a front upper cross portion and a rear upper cross portion that hold the headpipe **211** from the front and rear therebetween, while a single lower cross portion **52** is provided either only at the front or only at the rear of the headpipe **211**. As this occurs, a front lower or a rear lower portion of the link mechanism **5** can be used for other applications.

Additionally, in the preferred embodiments described above, while the link mechanism **5** is described as including the upper cross portion **51** and the lower cross portion **52**, the present invention is not limited thereto. For example, as the link mechanism, a link mechanism may be used which is configured to include three or more cross portions such as a link mechanism including an upper cross portion, a lower cross portion, and a middle cross portion provided between the upper cross portion and the lower cross portion.

In addition, in the preferred embodiments described above, while the upper cross portion **51** and the lower cross portion **52** are described as being mounted on the headpipe **211** that turnably supports the steering shaft **60**, the invention is not limited thereto. For example, the upper cross portion **51** and the lower cross portion **52** may be mounted at a location that extends upwards and forwards from the front frame **212** or a member mounted on the front frame **212** so as to extend upwards and forwards.

In the preferred embodiments described above, as shown in FIG. **4**, the lower cross portion **52** includes the front lower cross portion **52***a***1** and the rear lower cross portion **52***a***2** that are connected, respectively, to the front and rear of the headpipe **211** in such a manner as to hold the headpipe **211** therebetween in the front-and-rear direction of the body frame **21**. Additionally, the upper cross portion **51** is provided only at the front of the headpipe **211** in relation to the front-and-rear direction of the body frame **21**. However, the present invention is not limited thereto.

For example, as shown in FIG. **8**, a configuration may be used in which an upper cross portion **51**A includes a front upper cross portion **51**A**1** and a rear upper cross portion **51**A**2** that are individually connected to a headpipe **211** in such a manner as to hold the headpipe **211** therebetween in a front-and-rear direction of a body frame **21**. As this occurs, the front

upper cross portion **51**A1 has a volume larger than that of the rear upper cross portion **51**A2. By using this configuration, compared with a configuration in which the front upper cross portion **51**A1 has a volume the same or substantially the same as that of the rear upper cross portion **51**A2, the degree of freedom in designing a connecting portion of a front frame **212** to the headpipe **211** is enhanced. It is noted that in the configuration shown in FIG. **8**, displacements X1 to X4 are equal or substantially equal to one another.

Additionally, as this occurs, as shown in FIG. **8**, the volume of the front upper cross portion **51**A1 may be smaller than a volume of the front lower cross portion **52***a***1** that is located at a front portion of the lower cross portion **52**.

It is preferable that no constituent member of the link mechanism **5** is provided behind the headpipe **211** as shown in FIG. **4**. In the event that the configuration shown in FIG. **4** is used, the front frame **212** does not have to be connected to the headpipe **211** in such a manner as to bypass the rear upper cross portion **51**A2. Because of this, the front frame **212** can be connected to the headpipe **211** behind the upper cross portion **51**. By doing so, the rigidities of the front frame **212** and the headpipe **211** are enhanced without enlarging the front portion of the vehicle.

As shown in FIG. **8**, in the vehicle **1** according to the modified example, the body frame **21** includes the headpipe **211** that turnably supports the upper cross portion **51**A and the lower cross portion **52**A. In the link mechanism **5**, the front upper cross portion **51**A1 that defines a front portion of the upper cross portion **51**A that is located farther forward than the headpipe **211** in the direction of an upper right axis M3 has a smaller volume than that of a front lower cross portion **52***a***1** that defines a front portion of the lower cross portion **52**A that is located farther forward than the headpipe **211**.

According to the vehicle of this modified example that includes the body frame **21** that can lean and two front wheels **31**, **32**, the volume of the front upper cross portion **51**A1 that defines the front portion of the upper cross portion **51**A that is located farther forward than the headpipe **211** is smaller than the volume of the front lower cross portion **52***a***1** that defines the front portion of the lower cross portion **52** that is located farther forward than the headpipe **211**. Therefore, a movable range of the link mechanism **5** is changed from a simple shape like a rectangular parallelepiped to an irregular shape in which a front upper portion is smaller than a front lower portion. It is possible to enhance the degree of freedom in designing a peripheral space of the upper cross portion **51**A1. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery thereof.

In the vehicle according to a preferred embodiment, the body frame **21** includes the headpipe **211** that defines a portion of the body frame **21** that turnably supports the upper cross portion **51**A and the lower cross portion **52**A. The volume of the front upper cross portion **51**A1 that defines the front portion of the upper cross portion **51**A that is located farther forward than the headpipe **211** in the direction of the upper right axis M3 differs from the volume of the rear upper cross portion **51**A2 that defines a rear portion of the upper cross portion **51**A that is located farther rearward than the headpipe **211**.

According to the vehicle of a preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the volume of the front upper cross portion **51**A1 that is located farther forward than the headpipe **211** is different from the volume of the rear upper cross portion **51**A2 that is located farther rearward than the headpipe **211**. Therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to the irregular shape. This enhances the degree of freedom in designing the space around the periphery of the rear portion of the upper cross portion **51**A. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery thereof.

In the vehicle according to a preferred embodiment, the body frame **21** includes the headpipe **211** that turnably supports the upper cross portion **51**A and the lower cross portion **52**A. In the link mechanism **5**, the volume of the front lower cross portion **52***a***1** that defines the front portion of the lower cross portion **52**A that is located farther forward than the headpipe **211** in the direction of the upper right axis M3 differs from the volume of the rear lower cross portion **51***a***2** that defines a rear portion of the lower cross portion **52**A that is located farther rearward than the headpipe **211**.

According to the vehicle of a preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the volume of the front lower cross portion **52***a***1** that is located farther forward than the headpipe **211** differs from the volume of the rear lower cross portion **52***a***2** that is located farther rearward than the headpipe **211**, and therefore, the movable range of the link mechanism **5** is changed from the simple shape like a rectangular parallelepiped to the irregular shape.

This enhances the degree of freedom in designing the peripheral space at the rear portion of the lower cross portion **52**A. As a result of this, even though various on-board components that differ in size and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery thereof.

In the vehicle **1** according to a preferred embodiment, the upper cross portion **51**A includes a front upper cross portion **51**A1 (an example of an upper front portion) that is located farther forward than the headpipe **211** in the direction of the upper right axis M3 and a rear upper cross portion **51**A2 (an example of an upper rear portion) that is located farther rearward than the headpipe **211**.

According to the vehicle **1** of a preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the upper cross portion **51**A includes the front upper cross portion **51**A1 that is located farther forward than the headpipe **211** and the rear upper cross portion **51**A2 that is located farther rearward than the headpipe **211**, and therefore, the balance between the rigidity and the volume of the upper cross portion **51**A is easily controlled. This enhances the degree of freedom in designing the periphery of the lower portion of the steering shaft **60**. This enhances the degree of freedom in designing the space around the periphery of the upper cross portion **51**. As a result of this, even though various on-board portions having different sizes and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery of the steering shaft **60**.

According to a preferred embodiment, compared with a case where only the upper front portion is disposed at the front of the headpipe and no portion is disposed at the rear of the headpipe **211**, or a case where only the upper rear portion is disposed at the rear of the headpipe and no portion is disposed at the front of the headpipe, since the upper front portion **51**A1 and the upper rear portion **51**A2 hold the headpipe therebetween, it is easy to enhance the rigidity of the upper cross portion **51**A without enlarging the dimension of the

portion in the front-and-rear direction of the body frame **21**. This prevents the volume of the upper cross portion **51**A from being increased while enhancing the rigidity of the upper cross portion **51**A. This enhances the degree of freedom in designing the space around the periphery of the upper portion of the link mechanism. As a result of this, even though various on-board portions having different sizes and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery of the steering shaft **60**.

In the vehicle according to a preferred embodiment, the lower cross portion **52**A includes the front lower cross portion **52***a***1** (an example of a lower front portion) that is located farther forward than the headpipe **211** in the direction of the lower right axis M**6** and the rear lower cross portion **52***a***2** (an example of a lower rear portion) that is located farther rearward than the headpipe **211**.

According to the vehicle **1** of a preferred embodiment that includes the body frame **21** that can lean and the two front wheels **31**, **32**, the lower cross portion **52**A includes the front lower cross portion **52***a***1** that is located farther forward than the headpipe **211** and the rear lower cross portion **52***a***2** that is located farther rearward than the headpipe **211**, and therefore, the balance between the rigidity and volume of the lower cross portion **52**A is easily controlled. This enhances the degree of freedom in designing the periphery of the lower portion of the steering shaft **60**. This enhances the degree of freedom in designing the peripheral space at the rear portion of the lower cross portion **52**A. As a result of this, even though various on-board portions having different sizes and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery of the steering shaft **60**.

Compared with a case where only the lower front portion is disposed at the front of the headpipe and no portion is disposed at the rear of the headpipe, or a case where only the lower rear portion is disposed at the rear of the headpipe and no portion is disposed at the front of the headpipe, since the lower front portion **52***a***1** and the lower rear portion **52***a***2** hold the headpipe **211** therebetween, it is easy to enhance the rigidity of the lower cross portion **52**A without enlarging the dimension of the portion in the front-and-rear direction of the body frame **21**. This prevents the volume of the lower cross portion **52**A from being increased while enhancing the rigidity of the lower cross portion **52**A. This enhances the degree of freedom in designing the peripheral space at the rear portion of the link mechanism **5**. As a result of this, even though various on-board portions having different sizes and the link mechanism **5** are disposed around the periphery of the steering shaft **60**, it is possible to prevent the enlargement of the periphery of the steering shaft **60**.

In the preferred embodiments and modified examples described above, while the headpipe **211** is described as defining a portion of the link supporting portion, the present invention is not limited thereto. The front frame **212** of the body frame **21** may be used to turnably support the link mechanism **5**. Additionally, the link supporting portion may include a portion or a plurality of portions. In the case of the link supporting portion including a plurality of portions, the portions may be joined together through welding, bonding or the like. Alternatively, the portions may be joined together with fastening members such as bolts, rivets or the like.

The upper cross portion **51** may include an upper front cross portion, an upper rear cross portion, and a connecting member provided between the upper front and rear portions and including a plurality of portions. In the case of the link supporting portion including a plurality of portions, the portions may be joined together through welding, bonding or the like. Alternatively, the portions may be joined together with fastening members such as bolts, rivets or the like.

The lower cross portion **52** may include a lower front cross portion, a lower rear cross portion, and a connecting member provided between the lower front and rear portions and including a plurality of portions. In the case of the link supporting portion including a plurality of portions, the portions may be joined together through welding, bonding or the like. Alternatively, the portions may be joined together with fastening members such as bolts, rivets or the like.

Additionally, the right side portion **54** and the left side portion **53** may each be made up of a single portion or a plurality of portions. In the case of the link supporting portion including a plurality of portions, the portions may be joined together through welding, bonding or the like.
Alternatively, the portions may be joined together with fastening members such as bolts, rivets or the like. In addition, the right side portion **54** and the left side portion **53** may each include a portion disposed farther forward or a portion disposed farther rearward in the front-and-rear direction of the body frame **21** than the upper cross portion **51** or the lower cross portion **52**. The upper cross portion or the lower cross portion may be disposed between the portions that are disposed at the front and the portions that are disposed at the rear of the right side portion and the left side portion.

In the preferred embodiments described above, the right side portion **54**, the left side portion **53**, and the headpipe **211** are located at positions that are superposed one on another when the body frame **21** is seen from a side thereof. However, when the body frame **21** is seen from the side thereof, the headpipe **211** may be provided in a different position from positions where the right side portion **54** and the left side portion **53** are provided in relation to the front-and-rear direction. Additionally, leaning angles of the right side portion **54** and the left side portion **53** in relation to the up-and-down direction of the body frame **21** may differ from a leaning angle of the headpipe **211**.

The vehicle according to preferred embodiments of the present invention is preferably a vehicle that includes the body frame **21** that can lean and the two front wheels **31**, **32**. The number of rear wheels is not limited to one, and hence, the vehicle may include two rear wheels. Whether or not the vehicle includes the body cover that covers the body frame **21** is not a matter of question. As to the power source, an electric motor may be used in place of an engine.

When referred to in relation to the "direction" and the "member" in the present invention, the term "along" includes a case where the direction and the member are inclined within the range of ±40 degrees. When referred to in relation to the "direction" in the present invention, the term "extend" also includes a case where the direction is inclined within the range of ±40 degrees.

The upper middle axis M**1** and the lower middle axis M**4** may be referred to as a middle axis as a general term therefor. The upper cross portion **51** and the lower cross portion **52** may be referred to as a cross portion as a general term therefor. The right side portion **54** and the left side portion **53** may be referred to as a side portion as a general term therefor.

In the preferred embodiments of the present invention, the link mechanism **5** may further include a cross portion in addition to the upper cross portion **51** and the lower cross portion **52**. The upper cross portion **51** and the lower cross portion **52** are so called only because they are disposed relatively at an upper position and a lower position relatively. The upper cross portion **51** does not imply an uppermost cross portion in the link mechanism **5**. The upper cross portion may

indicate a cross portion positioned lower than an uppermost cross portion but is positioned higher than a different cross portion. The lower cross portion **52** does not imply a lowermost cross portion in the link mechanism. The lower cross portion may indicate a cross portion positioned higher than a lowermost cross portion but is positioned lower than a different cross portion. In addition, the cross portion may include three portions including a middle portion supported on the body frame, a right portion that supports the right side portion, and a left portion that supports the left side portion and the right cross portion and left cross portion that are divided transversely. In this manner, the upper cross portion and the lower cross portion may include a plurality of portions as long as they still provide the link function. The link mechanism only has to include the upper portion and the lower portion.

Additionally, in the preferred embodiments described above, the lower cross portion **52** is described as including two portions that are the flat plate-shaped rear lower cross portion **52***a***2** and the portion that includes the integral flat plate-shaped front lower cross portion **52***a***1** and the connecting portions **52***b* that connects the portion **52***a***1** and the rear lower cross portion **52***a***2** together. For example, by preparing the flat plate-shaped rear lower cross portion **52***a***2**, the flat plate-shaped front lower cross portion **52***a***1**, and the two connecting portions **52***b* as four independent portions, the lower cross portion **52** may be defined by these four portions.

When exerting the test forces, it is preferable that the test forces are exerted in such a state that the vehicle is fixed in the upright state. The forward direction in relation to the direction of the upper right axis indicates a direction directed from the rear portion to the front portion of the vehicle. The rearward direction in relation to the direction of the upper right axis indicates a direction directed from the front portion to the rear portion of the vehicle. The upper right axis, the lower right axis, the upper left axis, and the lower left axis are parallel or substantially parallel to one another. Because of this, the forward direction in relation to the direction of the upper right axis, the forward direction in the direction of the lower right axis, the forward direction in relation to the upper left axis, and the forward direction in relation to the lower left axis are the same or substantially the same in direction. The rearward direction in relation to the direction of the upper right axis, the rearward direction in the direction of the lower right axis, the rearward direction in relation to the upper left axis, and the rearward direction in relation to the lower left axis are the same or substantially the same in direction.

The test forces may be exerted directly on the bearings. Additionally, forces may be exerted directly to the side portion so that the test forces are eventually exerted on the bearings. The test force exerting method is not limited to these methods, as long as a method enables the test forces to be exerted on the bearings. The test forces may be exerted on the bearings by way of portions other than the side portion.

The terms and expressions that are used herein are used to describe the preferred embodiments of the present invention and hence should not be construed as limiting the scope of the present invention. It should be understood that any equivalents to the characteristic matters that are shown and described herein should not be excluded and that various modifications made within the scope of claims to be made later are permitted.

The present invention can be embodied in many different forms. The disclosure herein should be recognized as providing the preferred embodiments of the principle of the present invention. Based on the understanding that the preferred embodiments that are described and/or illustrated herein are not intended to limit the present invention thereto, several preferred embodiments are described and illustrated herein.

Several illustrated preferred embodiments of the invention are described herein. The present invention is not limited to the various preferred embodiments that are described herein. The present invention can include every preferred embodiment that includes equivalent elements, modifications, deletions, combinations (for example, combinations of the characteristics of the various preferred embodiments), improvements and/or alterations that those skilled in the art to which the present invention pertains can think of. Matters limited by claims should be construed widely based on terms that are used in the claims and should not be limited to the preferred embodiments described in this description or the prosecution of this patent application. Those preferred embodiments should be construed as non-exclusive. For example, in this disclosure, such terms as "preferred," "preferable" and "good" are non-exclusive terms and mean that "it is preferred but does not limit the present invention thereto," "it is preferable but does not limit the present invention thereto" and "it is good but does not limit the present invention thereto," respectively.

This patent application claims priority to Japanese Patent Application No. 2012-277219 filed on Dec. 19, 2012 and Japanese Patent Application No. 2012-277220 filed on Dec. 19, 2012, the contents of which are each incorporated herein by reference in their entirety.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

The invention claimed is:

1. A vehicle driven by power from a power source, the vehicle comprising:

a left front wheel and a right front wheel that are steerable and spaced apart in a left-and-right direction as seen from a front of the vehicle;

a right shock absorbing device that supports the right front wheel at a lower portion thereof and configured to absorb an upward displacement of the right front wheel in an up-and-down direction of a body frame;

a left shock absorbing device that supports the left front wheel at a lower portion thereof and configured to absorb an upward displacement of the left front wheel in the up-and-down direction of the body frame;

a link mechanism including:

a right side portion that supports an upper portion of the right shock absorbing device so as to turn about a right steering axis that extends in the up-and-down direction of the body frame;

a left side portion that supports an upper portion of the left shock absorbing device so as to turn about a left steering axis parallel or substantially parallel to the right steering axis;

an upper cross portion including a right end portion that supports an upper portion of the right side portion via an upper right bearing so as to turn about an upper right axis that extends in a front-and-rear direction of the body frame, a left end portion that supports an upper portion of the left side portion thereof via an upper left bearing so as to turn about an upper left axis parallel or substantially parallel to the upper right axis, and a middle portion supported on the body frame via an upper middle bearing so as to turn about

an upper middle axis parallel or substantially parallel to the upper right axis and the upper left axis; and

a lower cross portion includes a right end portion that supports a lower portion of the right side portion via a lower right bearing so as to turn about a lower right axis parallel or substantially parallel to the upper right axis, a left end portion that supports a lower portion of the left side portion thereof via a lower left bearing so as to turn about a lower left axis parallel or substantially parallel to the upper left axis, and a middle portion supported on the body frame via a lower middle bearing so as to turn about a lower middle axis parallel or substantially parallel to the upper middle axis;

a steering shaft supported on the body frame between the right side portion and the left side portion in a transverse direction of the body frame, including an upper end portion higher in the up-and-down direction of the body frame than the lower middle axis, and turnable about a middle steering axis that extends in the up-and-down direction of the body frame;

a handlebar provided at the upper end portion of the steering shaft; and

a turn transfer mechanism configured to transfer a turning motion of the steering shaft corresponding to an operation of the handlebar to the right shock absorbing device and to the left shock absorbing device; wherein

in the link mechanism:

the upper cross portion has a different volume than the lower cross portion; and

a displacement of the upper cross portion resulting when a forward or rearward test force in a direction of the upper right axis is exerted on the upper right bearing with the lower cross portion removed and the upper cross portion mounted, a displacement of the upper cross portion resulting when a force equal or substantially equal in magnitude and direction as the test force is exerted on the upper left bearing with the lower cross portion removed and the upper cross portion mounted, a displacement of the lower cross portion resulting when a force the same in magnitude and direction as the test force is exerted on the lower right bearing with the upper cross portion removed and the lower cross portion mounted, and a displacement of the lower cross portion resulting when a force the same in magnitude and direction as the test force is exerted on the lower left bearing with the upper cross portion removed and the lower cross portion mounted are equal or substantially equal to one another.

2. The vehicle according to claim **1**, wherein the upper cross portion is made of a material that is different from a material from which the lower cross portion is made.

3. The vehicle according to claim **1**, wherein the upper cross portion is made of a material that is identical to a material from which the lower cross portion is made.

4. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

a volume of a front portion of the upper cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis is different from a volume of a rear portion of the upper cross portion that is located farther rearward than the link supporting portion.

5. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

a volume of a front portion of the lower cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis is different from a volume of a rear portion of the lower cross portion that is located farther rearward than the link supporting portion.

6. The vehicle according to claim **1**, wherein the upper cross portion has a volume smaller than a volume of the lower cross portion.

7. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

a front portion of the upper cross portion that is located farther forward than the link supporting portion in the direction of the upper right axis has a volume smaller than a volume of a front portion of the lower cross portion that is located farther forward than the link supporting portion.

8. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

the upper cross portion or the lower cross portion is provided either forward of or rearward of the link supporting portion, but is not provided both forward and rearward of the link supporting portion.

9. The vehicle according to claim **1**, wherein a front end of the upper cross portion is located at a position that is different from a position where a front end of the lower cross portion is located in the direction of the upper right axis.

10. The vehicle according to claim **1**, wherein a rear end of the upper cross portion is located at a position that is different from a position where a rear end of the lower cross portion is located in the direction of the upper right axis.

11. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

the link supporting portion supports the steering shaft in a turnable manner.

12. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

the upper cross portion includes an upper front portion positioned farther forward than the link supporting portion in the direction of the upper right axis and that is supported at the right end portion and the left end portion and supported at the middle portion, and an upper rear portion positioned farther rearward than the link supporting portion in the direction of the upper right axis and that is supported at the right end portion and the left end portion and supported at the middle portion.

13. The vehicle according to claim **1**, wherein the body frame includes a link supporting portion that supports the upper cross portion and the lower cross portion in a turnable manner; and

the lower cross portion includes a lower front portion positioned farther forward than the link supporting portion in the direction of the lower right axis and that is supported at the right end portion and the left end portion and supported at the middle portion, and a lower rear portion

positioned farther rearward than the link supporting portion in the direction of the lower right axis and that is supported at the right end portion and the left end portion and supported at the middle portion.

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